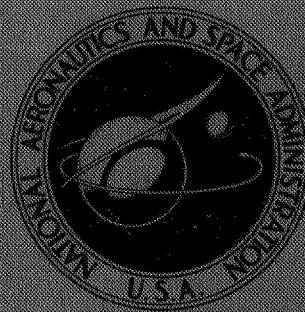


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AERODYNAMIC CHARACTERISTICS IN PITCH OF A
MODIFIED-HALF-RING-WING—BODY COMBINATION
AND A SWEEP-WING—BODY COMBINATION
AT MACH 2.16 TO 3.70

by Odell A. Morris and Milton Lamb
Langley Research Center
Langley Station, Hampton, Va.

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SUMMARY

An investigation has been conducted in the Langley Unitary Plan wind tunnel at Mach numbers from 2.16 to 3.70 to determine the aerodynamic characteristics in pitch of a modified-half-ring-wing model. The investigation also included tests of a swept-wing model. Both models had a wide flat body and could be fitted with various forebody and afterbody sections.

Results of the investigation indicated that favorable interference-lift effects were obtained for both wing-body models at zero angle of attack, the largest effects occurring for the modified-half-ring-wing model. The maximum lift-drag ratios, however, were obtained with the swept-wing model since it produced greater lift-curve slopes than the modified-half-ring-wing model. The changes in forebody and afterbody shapes investigated for both models produced no significant changes in maximum lift-drag ratios, as compared with the ratios for the basic symmetrical body shape.

INTRODUCTION

Much work has been done in recent years on the subject of favorable interference in supersonic flow. Several of these studies have been directed toward the use of the ring-wing—body configuration as a means of reducing wave drag. (See refs. 1 to 4.) The investigations of references 3 and 4 have shown that in the case of a half-ring-wing configuration, the pressure field produced by the forebody results in a favorable lift increment on the wing. However, the lifting efficiency of the half-ring wing is low and, combined with other factors such as large skin-friction drag (because of the high ratio of wing wetted area to wing planform area), results in lower maximum lift-drag ratios than those of more conventional wing-body configurations.

In an effort to obtain improved performance of the half-ring wing, an investigation has been made of several experimental configurations, which consist primarily of a

modified-half-ring-wing—body model and a swept-wing—body model. The bodies of the configurations were made unusually broad and flat in an attempt to obtain improved interference-lift effects from the forebody pressure on the wing. Various shaped forebody and afterbody sections could be incorporated into the models.

Tests have been conducted in the Langley Unitary Plan wind tunnel at Mach numbers from 2.16 to 3.70 through an angle-of-attack range of about -4° to 10° to determine the aerodynamic characteristics in pitch of the configurations. Results of the investigation, together with a limited analysis, are presented herein.

SYMBOLS

The data in the present investigation are referred to the stability-axes system, the moment reference point being located 15.75 inches (40.005 cm) rearward of the nose of the body. U.S. Customary Units are used, and the units for the International System are given parenthetically.

C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
$C_{L\alpha}$	lift-curve slope, $\frac{\partial C_L}{\partial \alpha}$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSc}$
c	wing reference chord, 11.00 inches (27.940 centimeters)
L/D	lift-drag ratio
M	free-stream Mach number
q	free-stream dynamic pressure, pounds/foot ² (newtons/meter ²)
R	Reynolds number
S	reference wing planform area, 1.65 feet ² (0.153 meter ²)
V	volume
α	angle of attack, degrees

Subscripts:

max maximum

min minimum

MODELS AND APPARATUS

The models incorporated two wings, which are referred to herein as the swept wing and the modified half-ring wing. Details of the models are shown in figure 1, and a photograph of the model with the modified half-ring wing is shown in figure 2. Both wings were characterized by a planform area of 1.65 feet² (0.153 meter²) and by double-wedge airfoil sections having a thickness ratio of 3 percent. The half-ring wing used in this investigation was a modification of the basic half-ring wing in that it had a flat center section the width of the nose. It was positioned to reflect the body nose shock at a Mach number of 3.00 and an angle of attack of 0°. The swept wing had a leading-edge sweep of 62.5° and was also positioned to reflect the body nose shock at the same conditions. The wings were mounted above the body on struts that had a streamwise thickness ratio of 4 percent.

The basic body had a 10°-symmetrical-wedge nose and a 7°-symmetrical-wedge afterbody. These body sections were removable so that tests could also be made with either flat-top or flat-bottom body sections.

The wing-body models were sting-mounted in the tunnel, and the forces and moments were measured by means of a six-component strain-gage balance mounted within the model.

TESTS AND CORRECTIONS

The tests were conducted in the Langley Unitary Plan wind tunnel at a stagnation temperature of 150° F (338° K) at Mach numbers of 2.16, 2.50, 2.86, 3.00, 3.35, and 3.70. The dewpoint was held sufficiently low to prevent measurable condensation effects in the test section. Tests were made through an angle-of-attack range of about -4° to 10° at a Reynolds number per foot of 2.0×10^6 (6.6×10^6 per meter). The angles of attack were corrected for deflection of the balance and sting under load and for tunnel-flow angularity. The balance-chamber pressures were measured, and the drag forces were adjusted to correspond to a condition of free-stream static pressure at the model base. In order to provide turbulent boundary-layer conditions, transition strips 0.0625 inch (0.159 cm) wide of No. 60 carborundum grit were applied 0.5 inch (1.27 cm), measured streamwise, from the body nose and the leading edges of the wings and struts.

PRESENTATION OF RESULTS

The results of the investigation and the figures in which they are presented are as follows:

Effect of nose shape on the aerodynamic characteristics in pitch for the swept-wing model with the symmetrical afterbody at $M = 2.16, 2.50, \text{ and } 2.86$	3
Effect of afterbody shape on the aerodynamic characteristics in pitch for the swept-wing model with the symmetrical nose at $M = 3.00, 3.35, \text{ and } 3.70$	4
Effect of nose shape on the aerodynamic characteristics in pitch for the modified-half-ring-wing model with the flat-bottom afterbody at $M = 2.16, 2.50, \text{ and } 2.86$	5
Effect of afterbody shape on the aerodynamic characteristics in pitch for the modified-half-ring-wing model with the symmetrical nose at $M = 3.00, 3.35, \text{ and } 3.70$	6
Aerodynamic characteristics in pitch of the body alone with the symmetrical nose and afterbody at $M = 3.00, 3.35, \text{ and } 3.70$	7
Variation of the longitudinal parameters with Mach number for the two wing-body models with the symmetrical nose	8
Schlieren photographs of the models at $M = 3.00$	9

DISCUSSION

The data of figures 3 and 5 show the effect of changes in body nose shape for the swept-wing model and the modified-half-ring-wing model at Mach numbers from 2.16 to 2.86. Changes in nose shape from symmetrical wedge to either flat top or flat bottom generally reduce the maximum L/D values for both models. In addition, significant changes in the zero-lift pitching-moment coefficient $C_{m,0}$ are produced by changes in nose shape.

Changing the afterbody shape from symmetrical wedge to flat bottom produces somewhat higher maximum L/D values for both models at Mach numbers from 3.00 to 3.70. (See figs. 4 and 6.) However, the flat-bottom afterbody also produces a negative $C_{m,0}$ increment which would probably cancel the increase obtained in L/D if trim conditions for the configurations were considered.

The data of figure 7 show the aerodynamic characteristics in pitch of the body alone with the symmetrical nose and afterbody at Mach numbers from 3.00 to 3.70. These data show that the body alone at $M = 3.00$ has a maximum L/D value of about 3.9, which is a large percentage of the maximum L/D values for the wing-body combinations. However, the maximum L/D values for the body alone occur at a much higher angle of attack than that for the wing-body combinations.

The data of figure 8 show a comparison of several longitudinal parameters for three representative configurations over the Mach number range. The L/D value at $\alpha = 0^\circ$ is a measure of the interference lift produced by the forebody pressure on the wing, the largest values being shown for both models at Mach numbers of about 3.00. At this Mach number, the entire shock wave is reflected by the wing. (See schlieren photographs in fig. 9, $\alpha = -0.24^\circ$.) As the angle of attack is increased, the shock wave moves forward of the wing; thus the favorable interference lift produced by the positive pressures from the forebody is gradually decreased. Also, the negative pressure field produced by the expansion wave from the forebody shoulder moves forward on the wing so that at the higher test angles negative interference lift would be expected. At $\alpha = 0^\circ$, the modified-half-ring-wing model has higher L/D values than the swept-wing model; however, the $(L/D)_{\max}$ values are larger for the swept-wing model because its lift-curve slopes are nearly twice as large as the slopes for the modified-half-ring-wing model. (See fig. 8.) Thus, even though the curved section of the modified half-ring wing provides a larger favorable interference lift than the swept wing at zero angle of attack, the modified half-ring wing does not have the lifting capability at higher angles of attack comparable to the capability of the swept wing, which has the same wing surface area (but greater planform area).

It is also interesting to note that the maximum L/D value obtained was about 6.0 at a Mach number of 3.0, which is slightly lower than the value obtained for the conventional swept-wing—body model of reference 5. Therefore, it appears that these models offer no performance advantage over a conventional wing-body model. However, it should be pointed out that the 74° -swept-wing—body model of reference 5 has a body with considerably less volume and represents the best in aerodynamic performance at the present time.

CONCLUSIONS

An investigation has been conducted in the Langley Unitary Plan wind tunnel at Mach numbers from 2.16 to 3.70 to determine the aerodynamic characteristics in pitch of a modified-half-ring-wing model. The investigation also included tests of a swept-wing model. The following results were indicated:

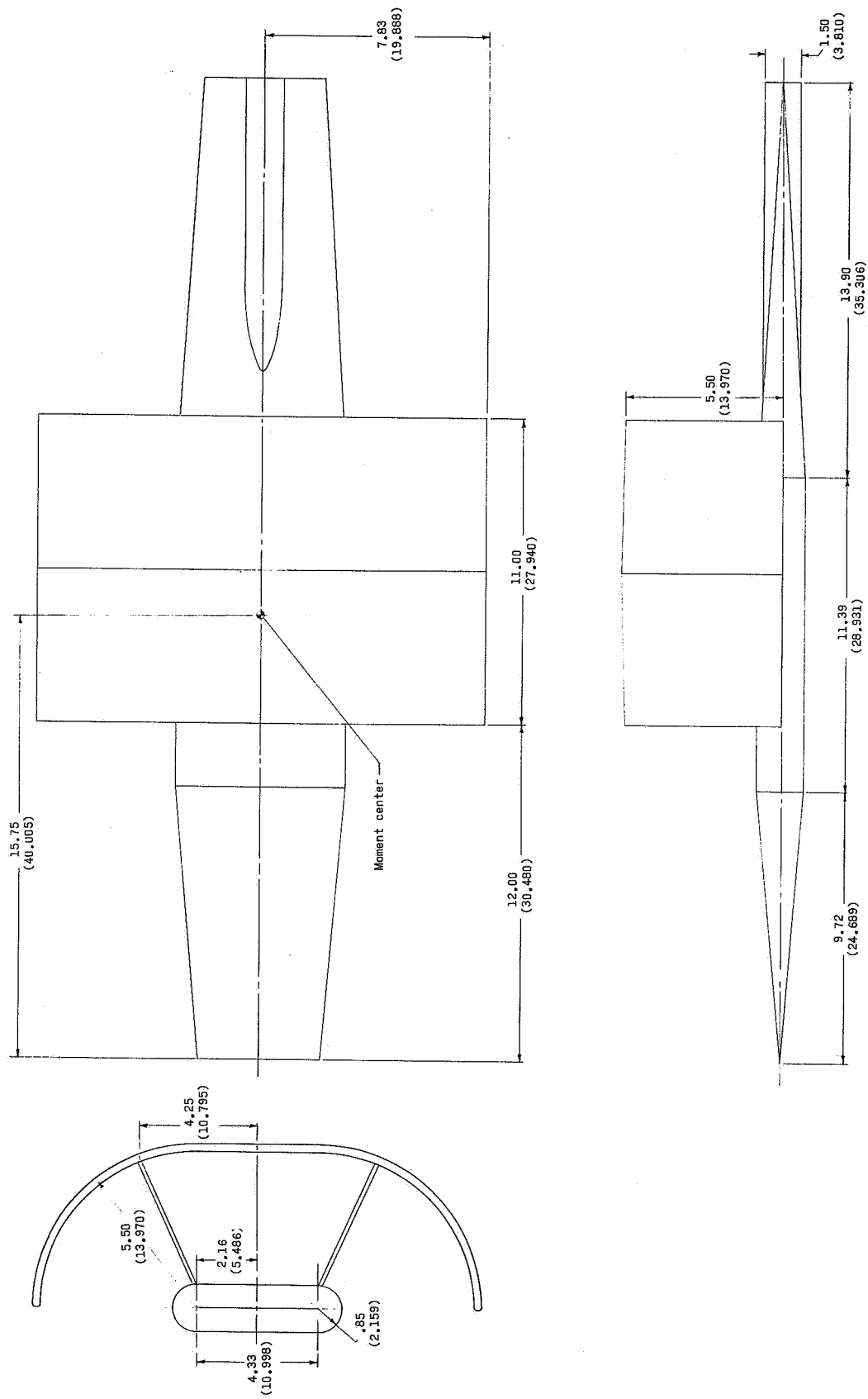
1. Favorable interference-lift effects were obtained for both wing-body models at zero angle of attack, the largest effects occurring for the modified-half-ring-wing model.
2. The maximum lift-drag ratios, however, were obtained with the swept-wing model since it produced considerably greater lift-curve slopes than the modified-half-ring-wing model.

3. The changes in forebody and afterbody shapes investigated for both models produced no significant changes in maximum lift-drag ratios, as compared with the ratios of the basic symmetrical body shape. However, substantial changes in zero-lift pitching-moment coefficient and hence, trim characteristics, were found.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., December 5, 1967,
126-13-02-08-23.

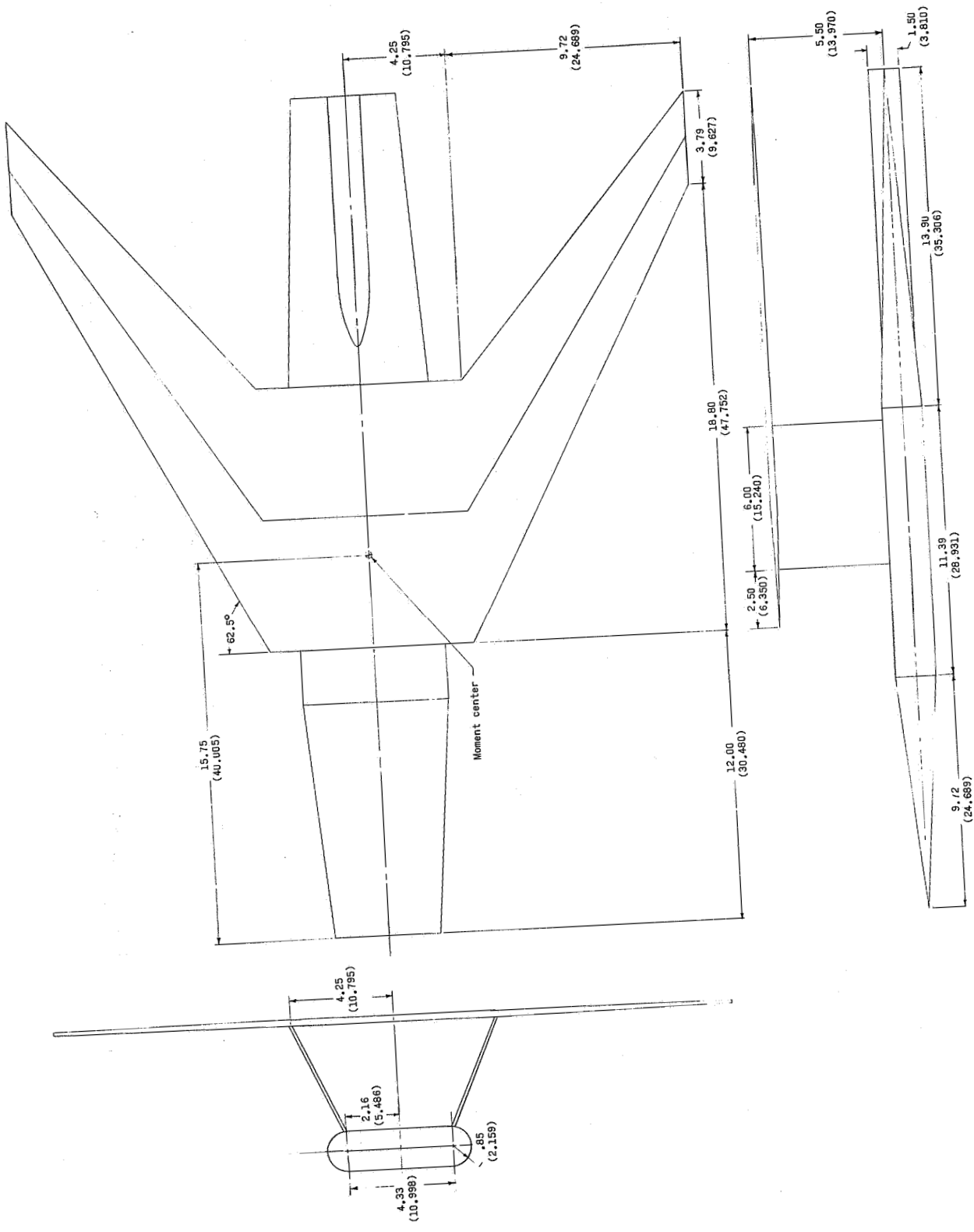
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1. Johnson, Roger P.: Verification of Ring-Wing Theory. U.S. Air Force Project RAND Briefing B-224 (Contract No. AF 49(638)-700), The RAND Corp., Jan. 4, 1961.
2. Browand, Frederick K.; Beane, Beverly J.; and Nowlan, Daniel T.: The Design and Test at Mach Number 2.5 of Two Low-Wave-Drag Ring-Wing Configurations of Aspect Ratio 1.3 and 2.6. RM-2933-PR, The RAND Corp., June 1962.
3. Moore, K. C.; and Jones, J. G.: Some Aspects of the Design of Half-Ring Wing-Body Combinations With Prescribed Wing Loadings. Tech. Note No. Aero 2860, Brit. R.A.E., Dec. 1962.
4. Morris, Odell: Aerodynamic Characteristics in Pitch of Several Ring-Wing—Body Configurations at a Mach Number of 2.2. NASA TN D-1272, 1962.
5. Morris, Odell A.: Aerodynamic Characteristics of Various Configurations of a Wing-Body Model With a 74° Swept Warped Wing. NASA TM X-1472, 1967.



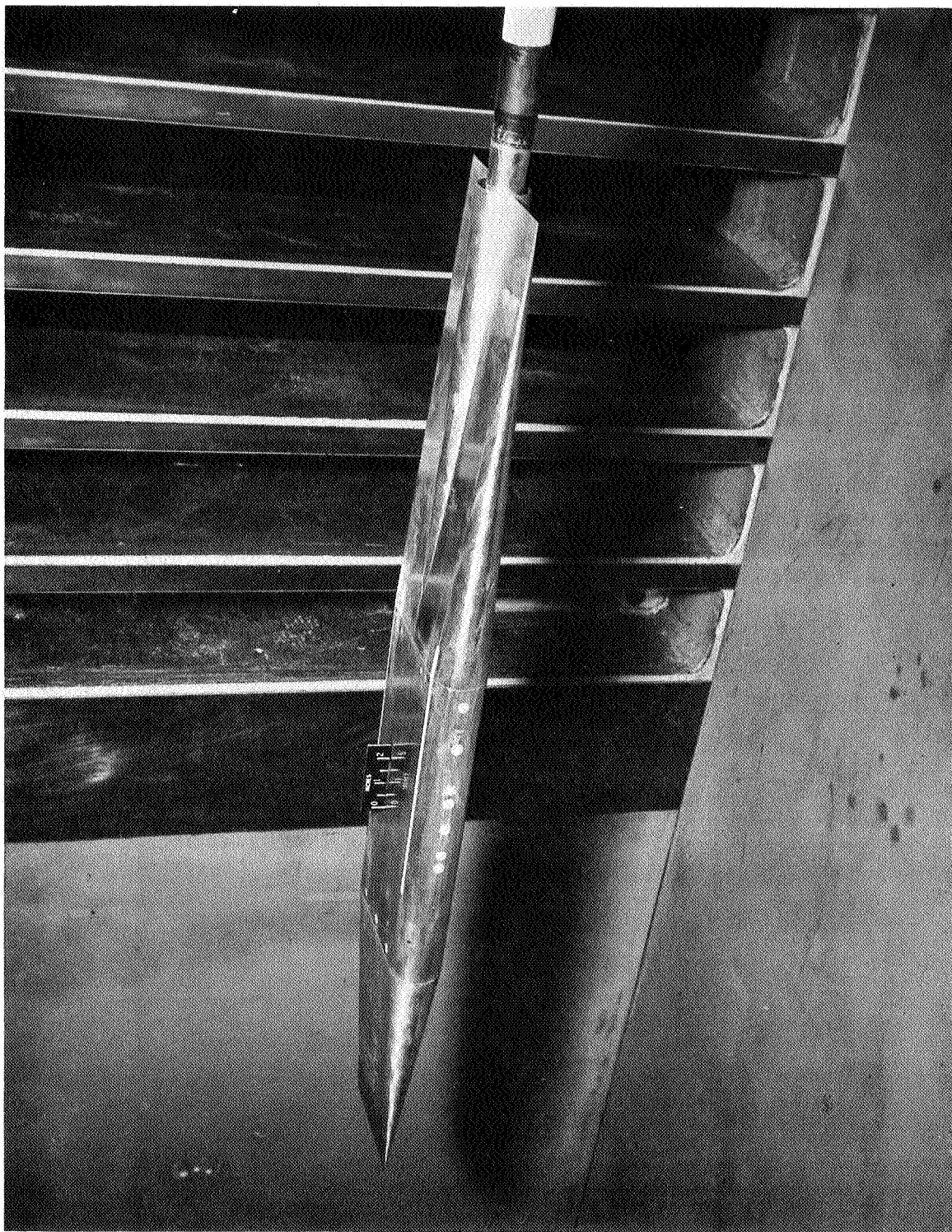
(a) Modified-half-ring-wing—body model.

Figure 1.- Details of models. All dimensions are given in inches and parenthetically in centimeters.



(b) Swept-wing-body model.

Figure 1.- Concluded.



(a) Body alone.

Figure 2.- Photographs of models.

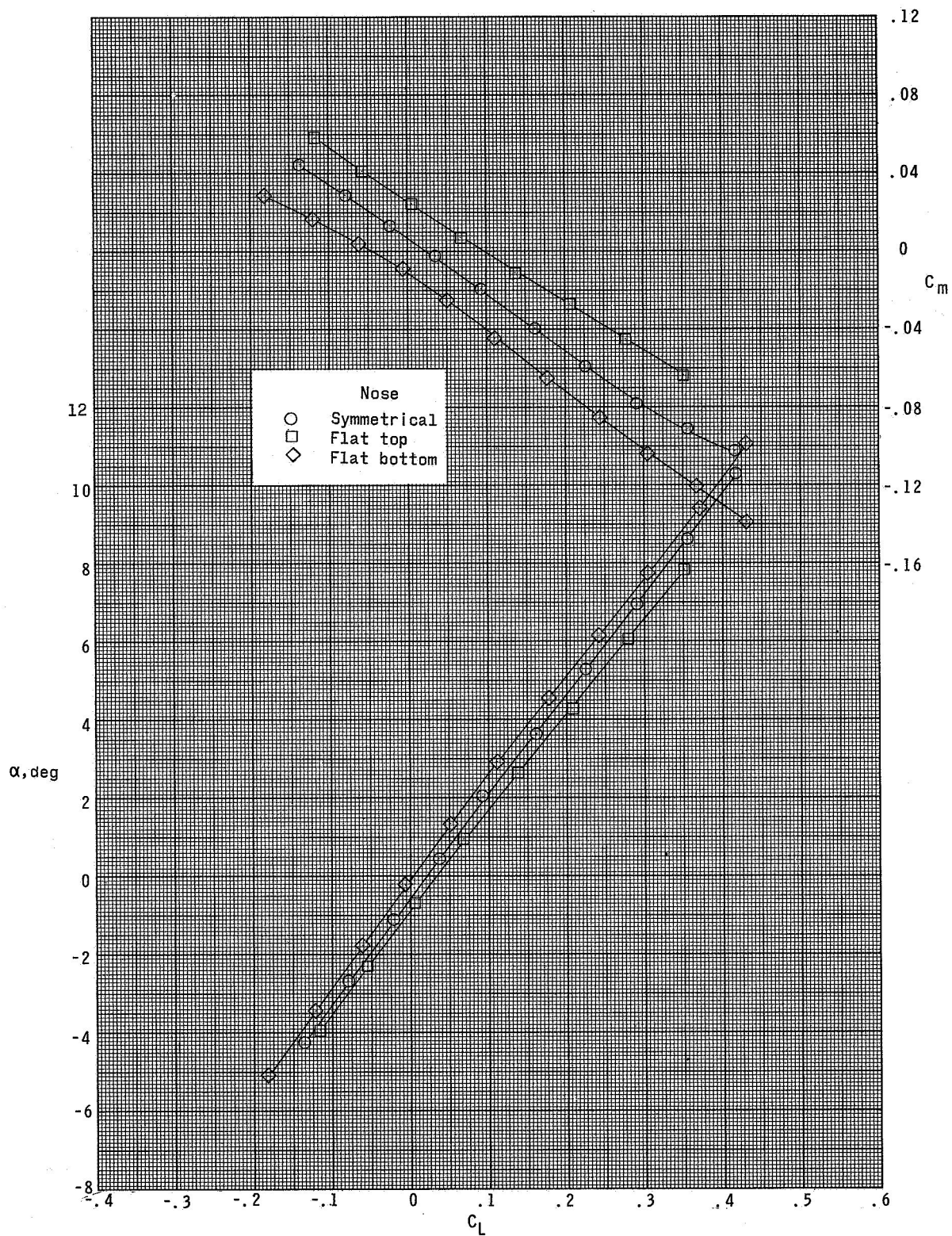
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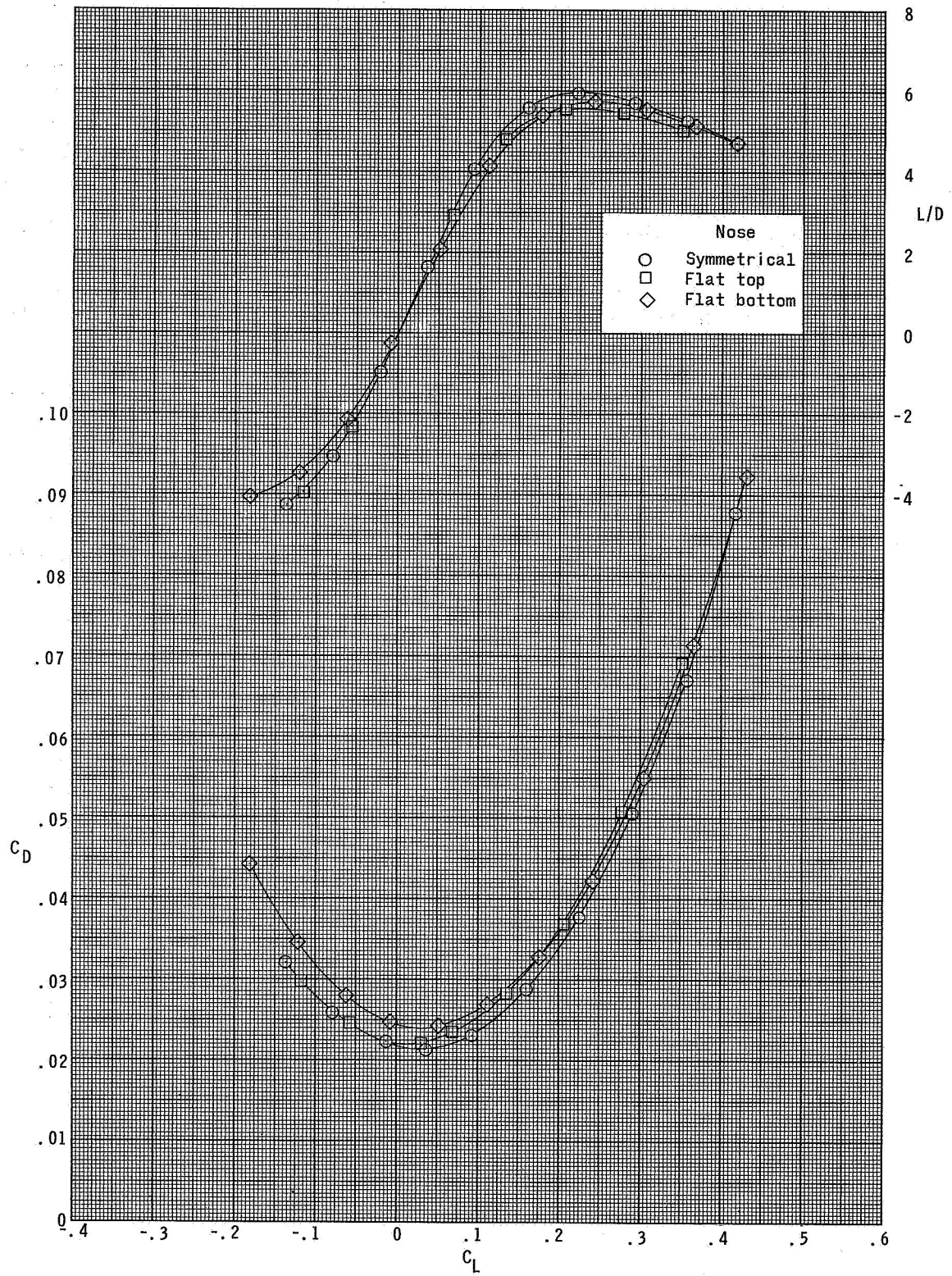
(b) Body with modified half-ring wing.

Figure 2.- Concluded.



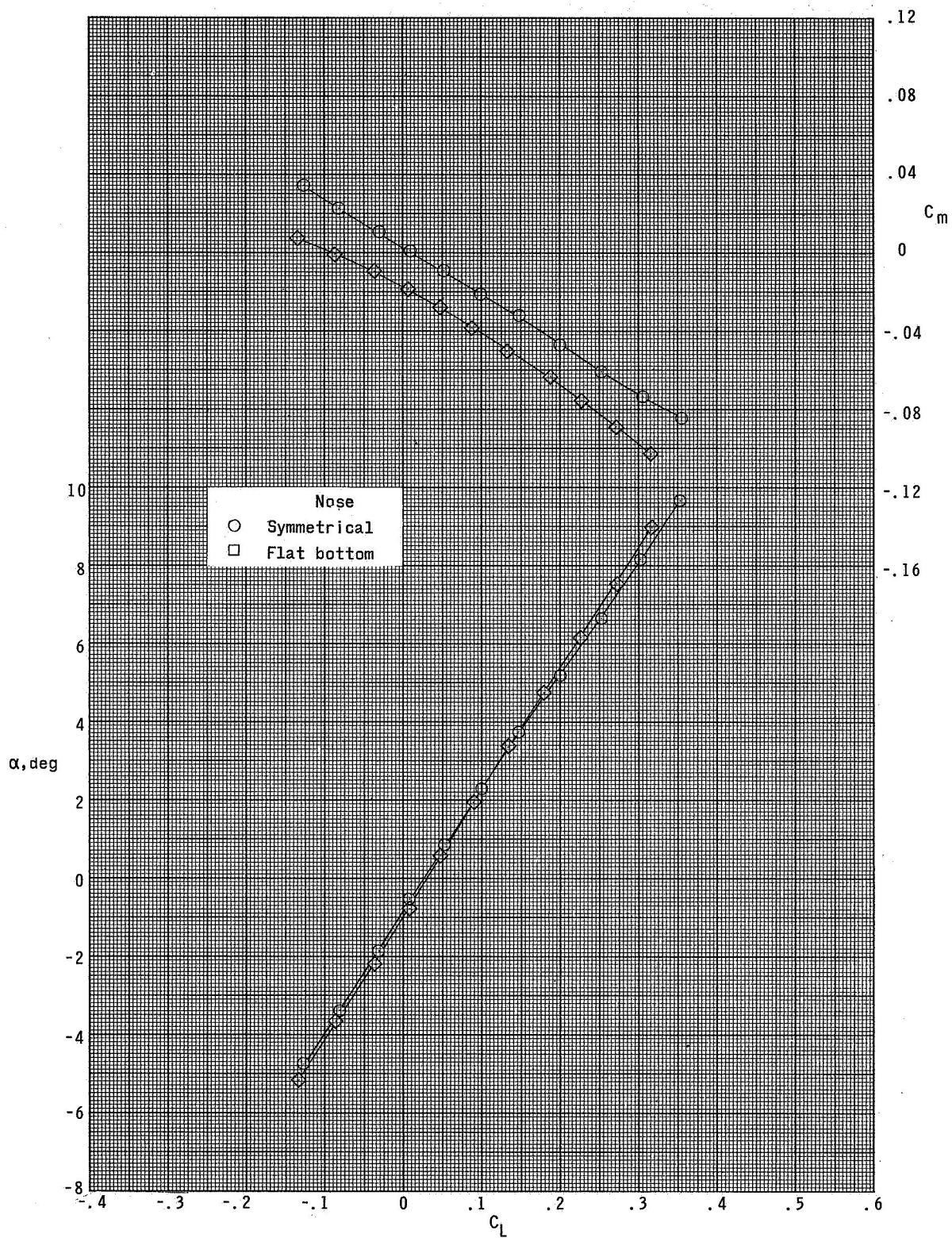
(a) $M = 2.16$.

Figure 3.- Effect of nose shape on the aerodynamic characteristics in pitch for the swept-wing model with the symmetrical afterbody.



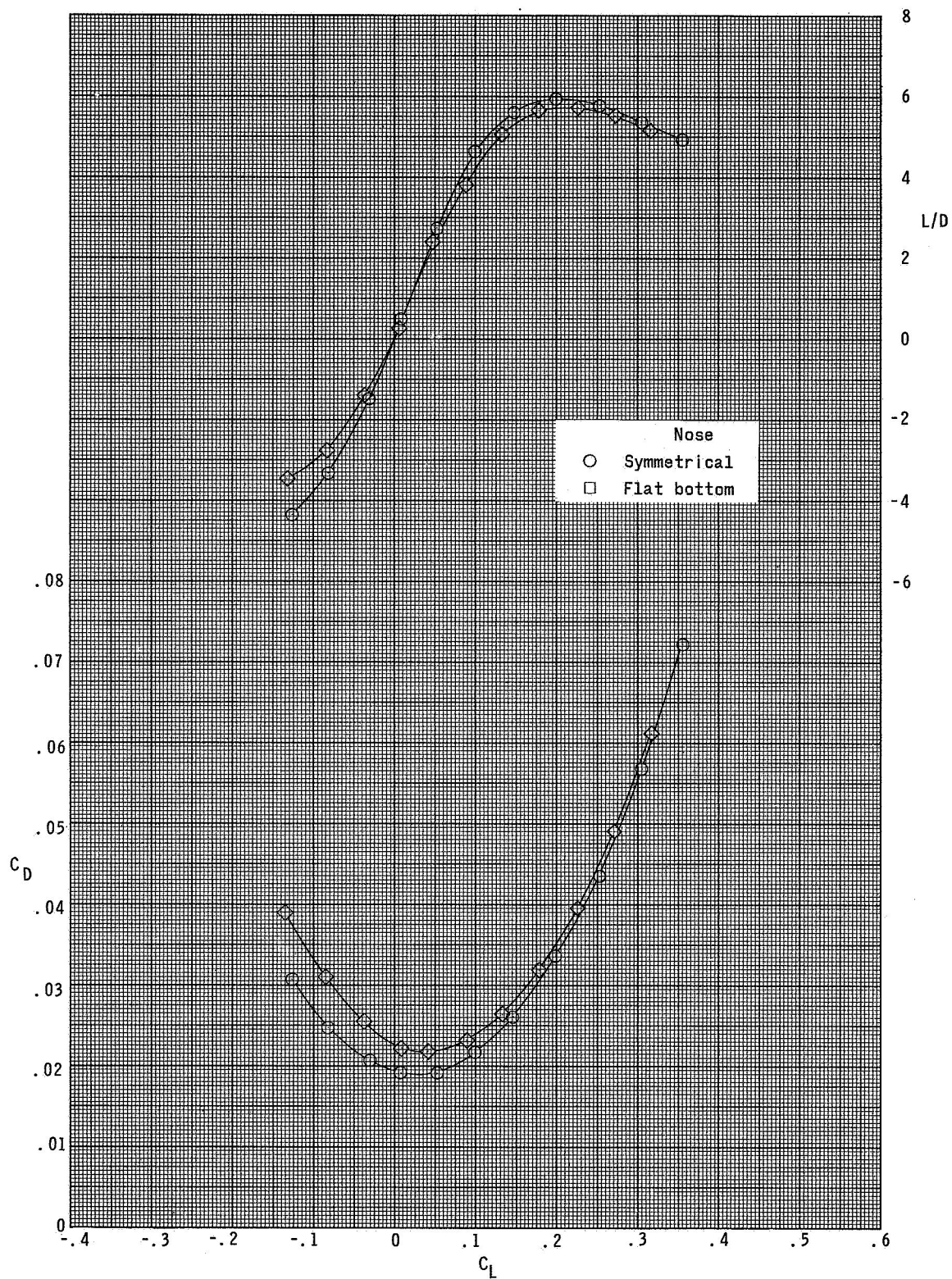
(a). $M = 2.16$. Concluded.

Figure 3.- Continued.



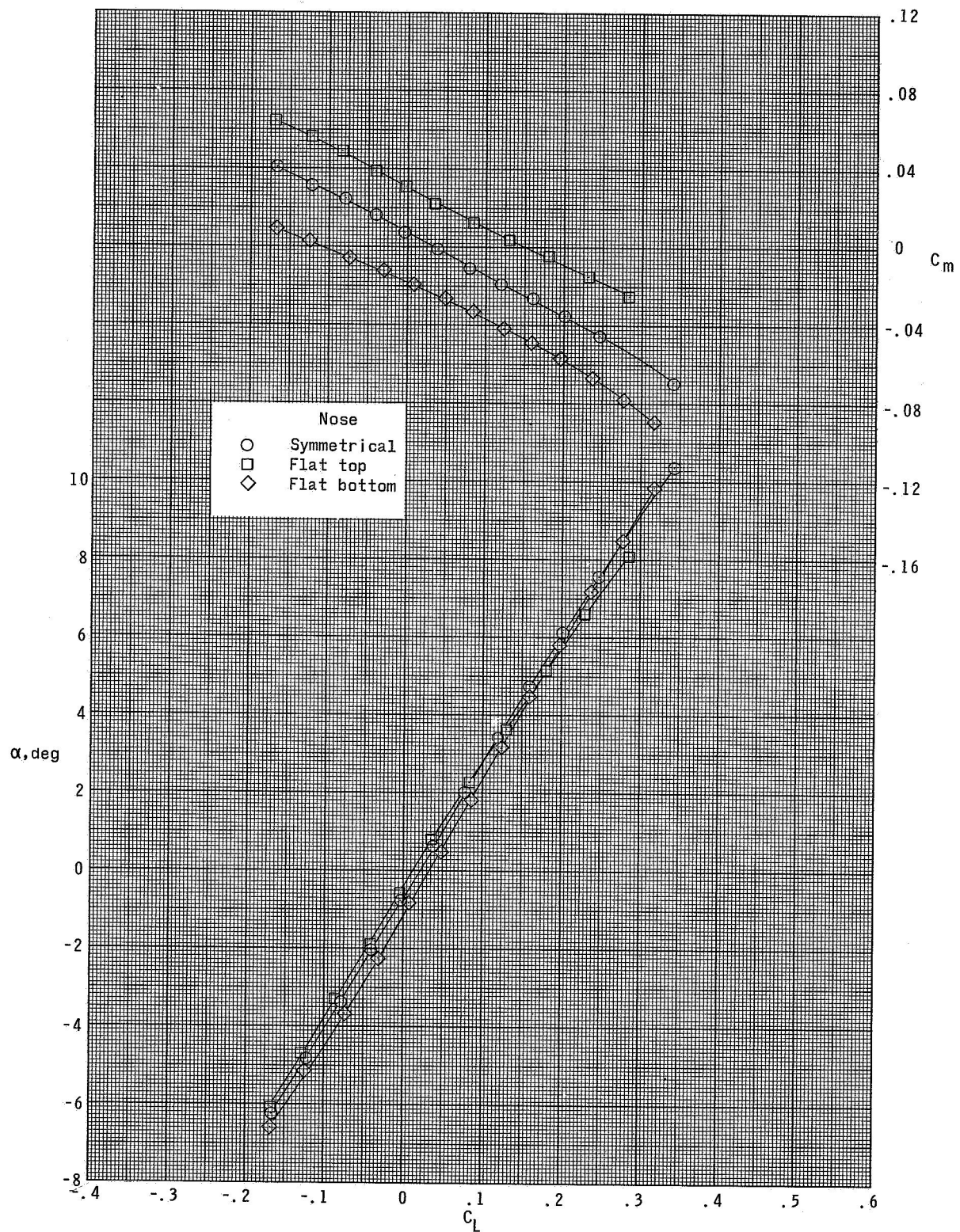
(b) $M = 2.50$.

Figure 3.- Continued.



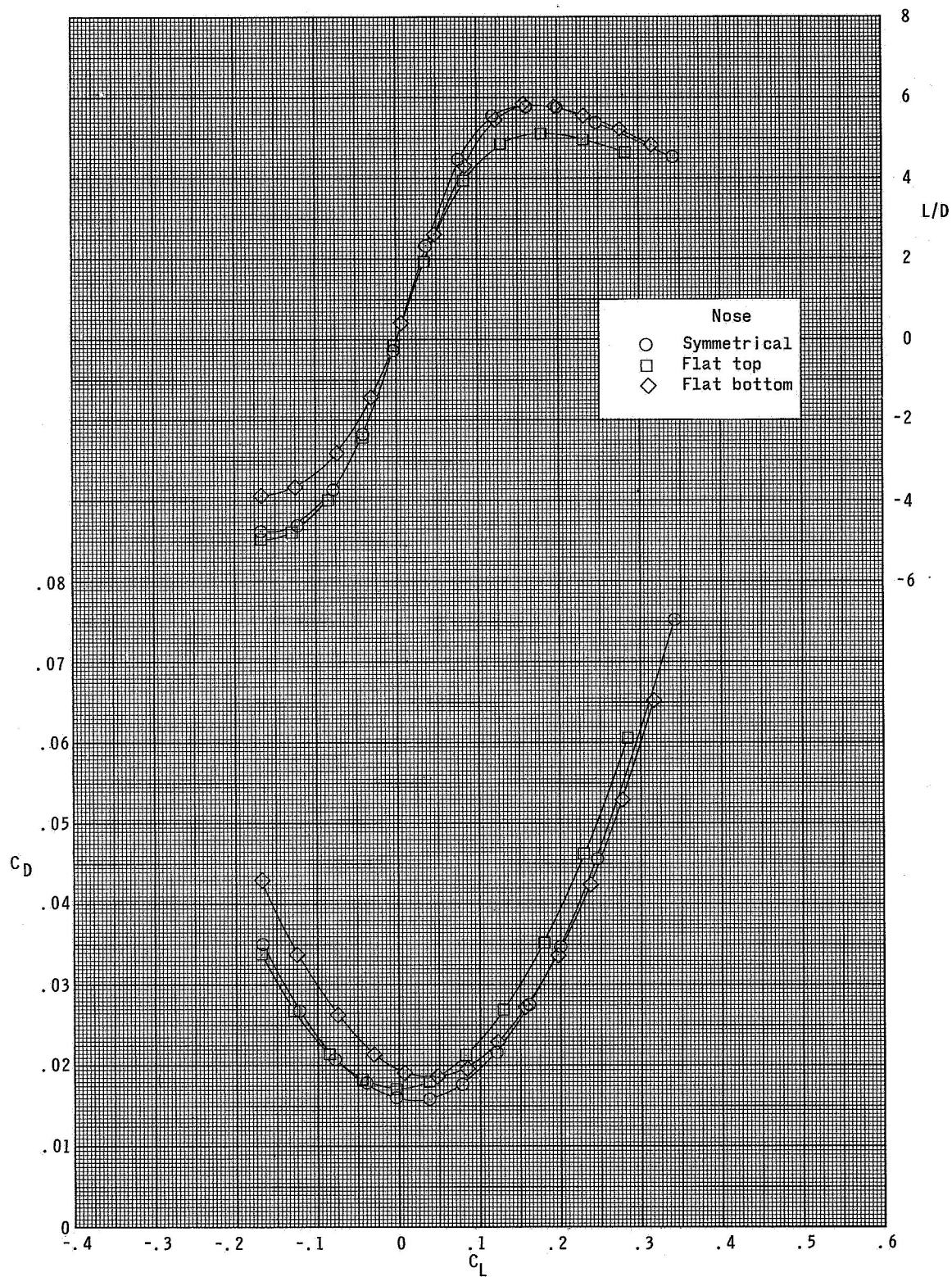
(b) $M = 2.50$. Concluded.

Figure 3.- Continued.



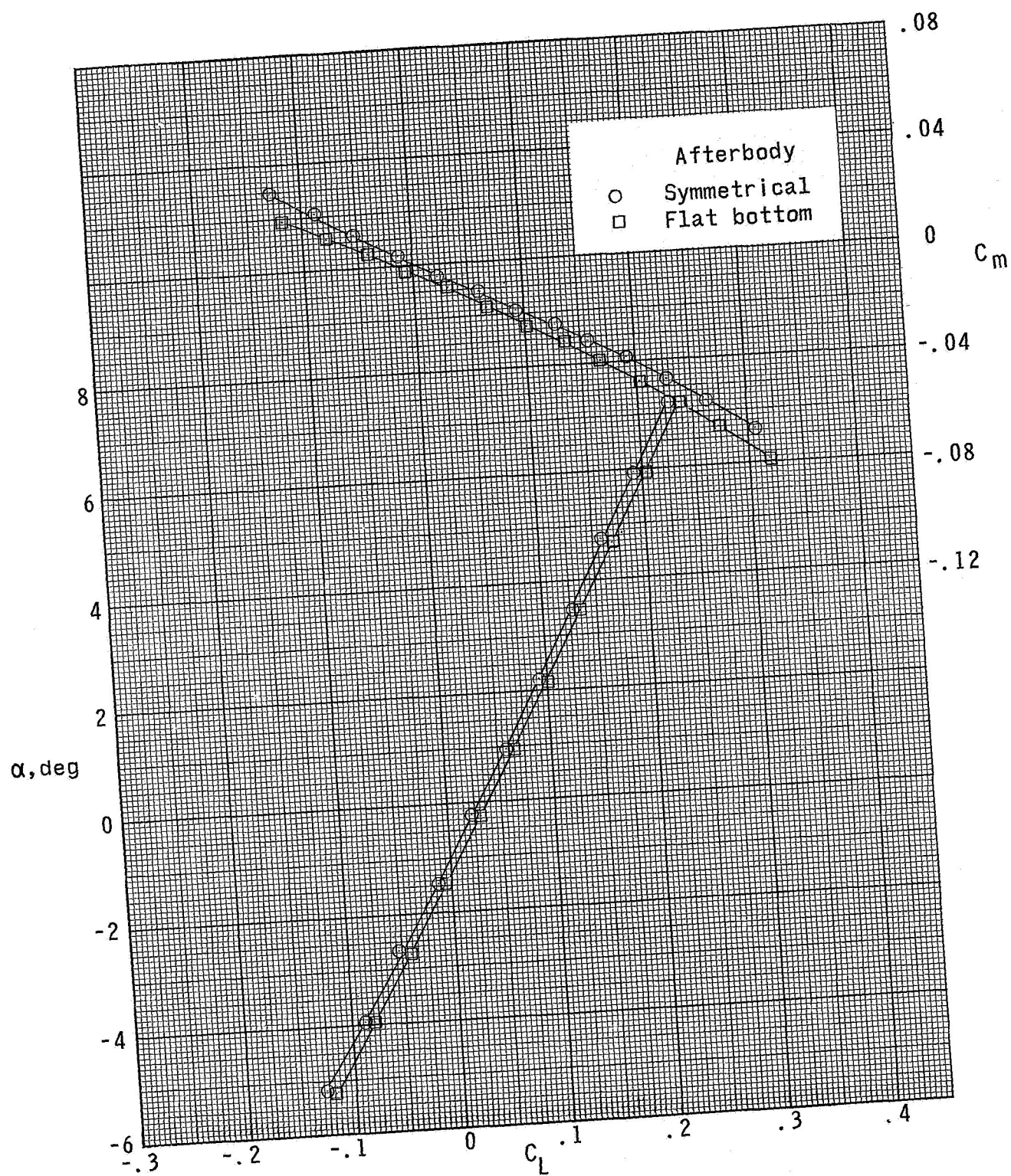
(c) $M = 2.86$.

Figure 3.- Continued.



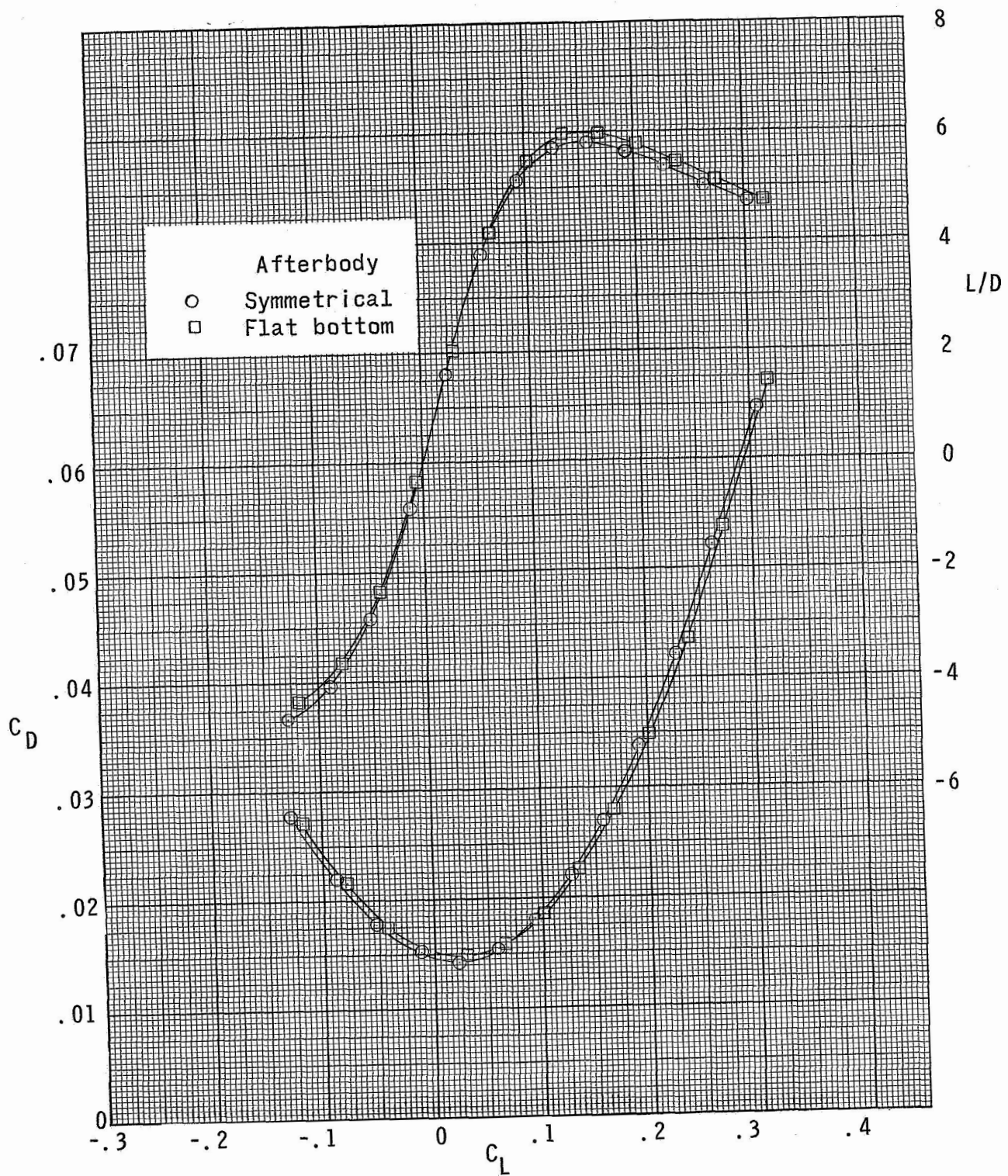
(c) $M = 2.86$. Concluded.

Figure 3.- Concluded.



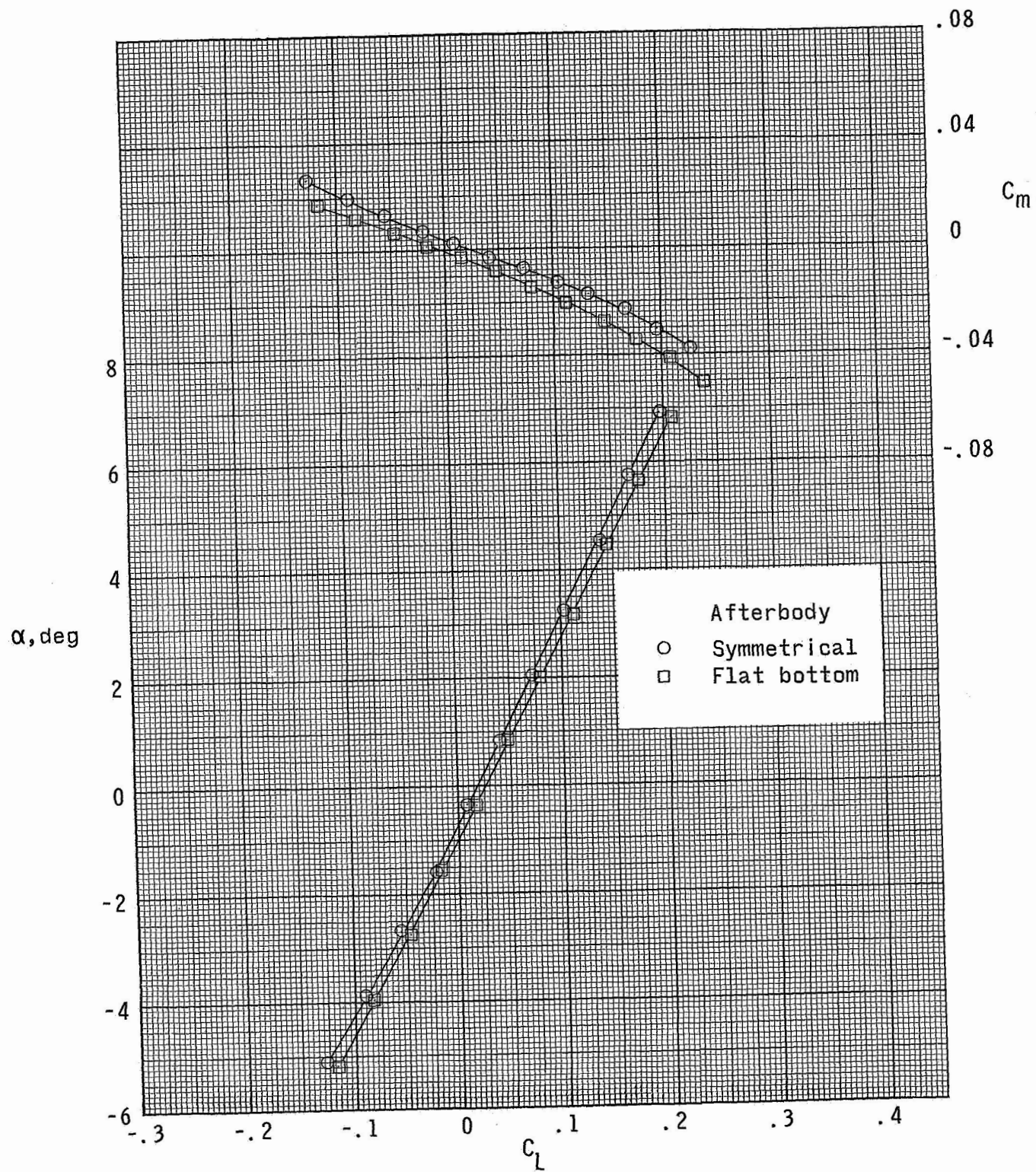
(a) $M = 3.00$.

Figure 4.- Effect of afterbody shape on the aerodynamic characteristics in pitch for the swept-wing model with the symmetrical nose.



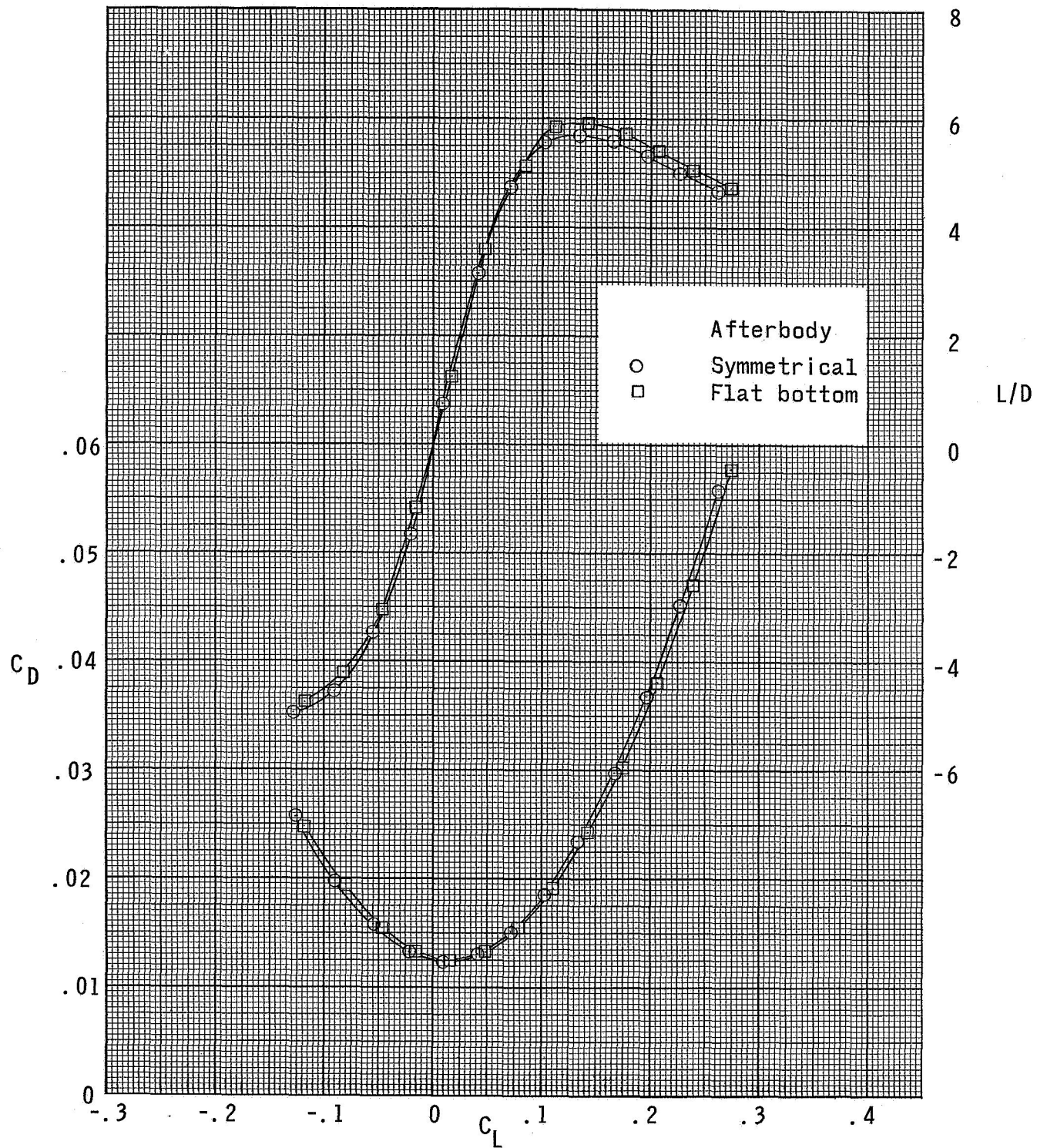
(a) $M = 3.00$. Concluded.

Figure 4.- Continued.



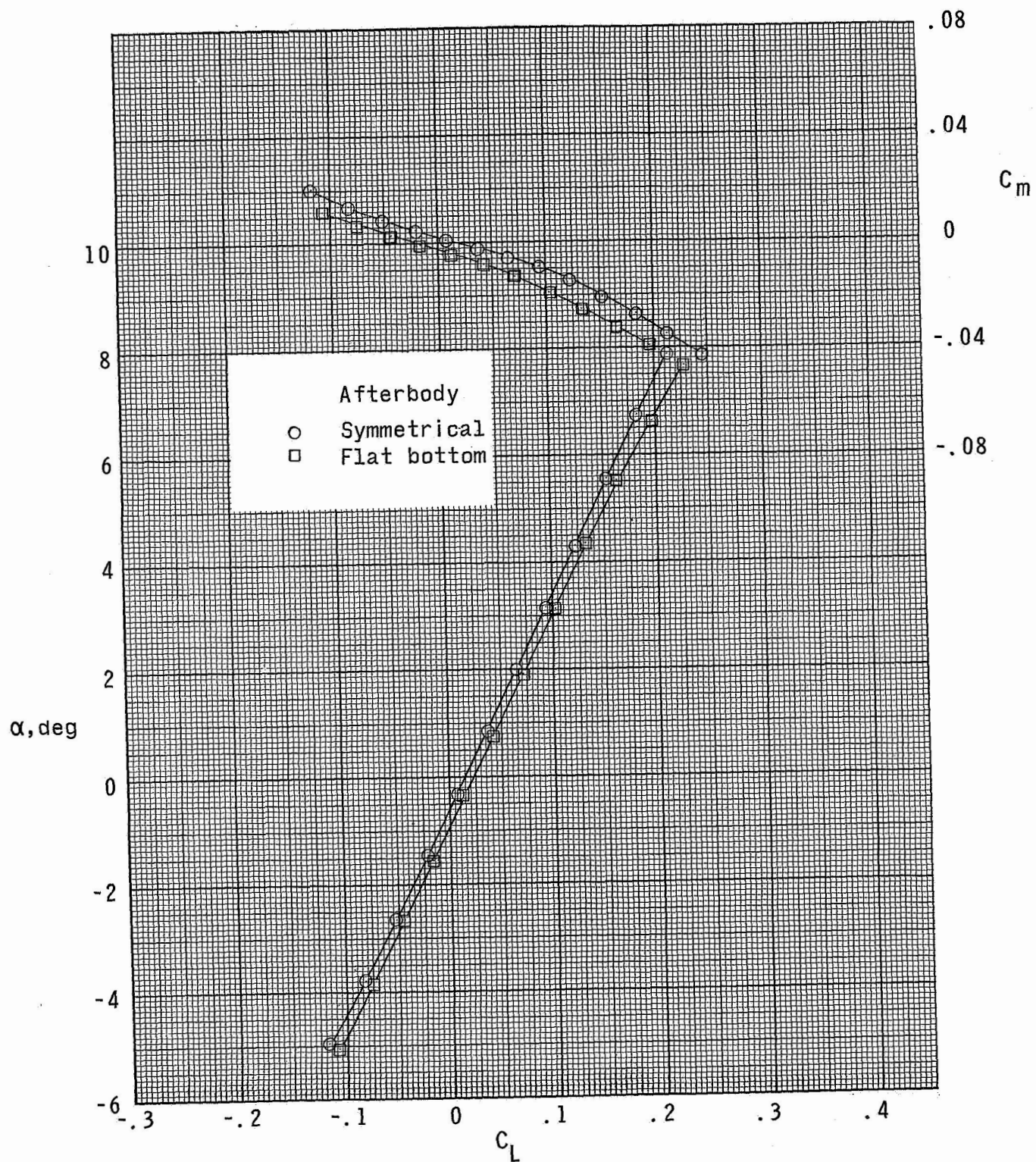
(b) $M = 3.35$.

Figure 4.- Continued.



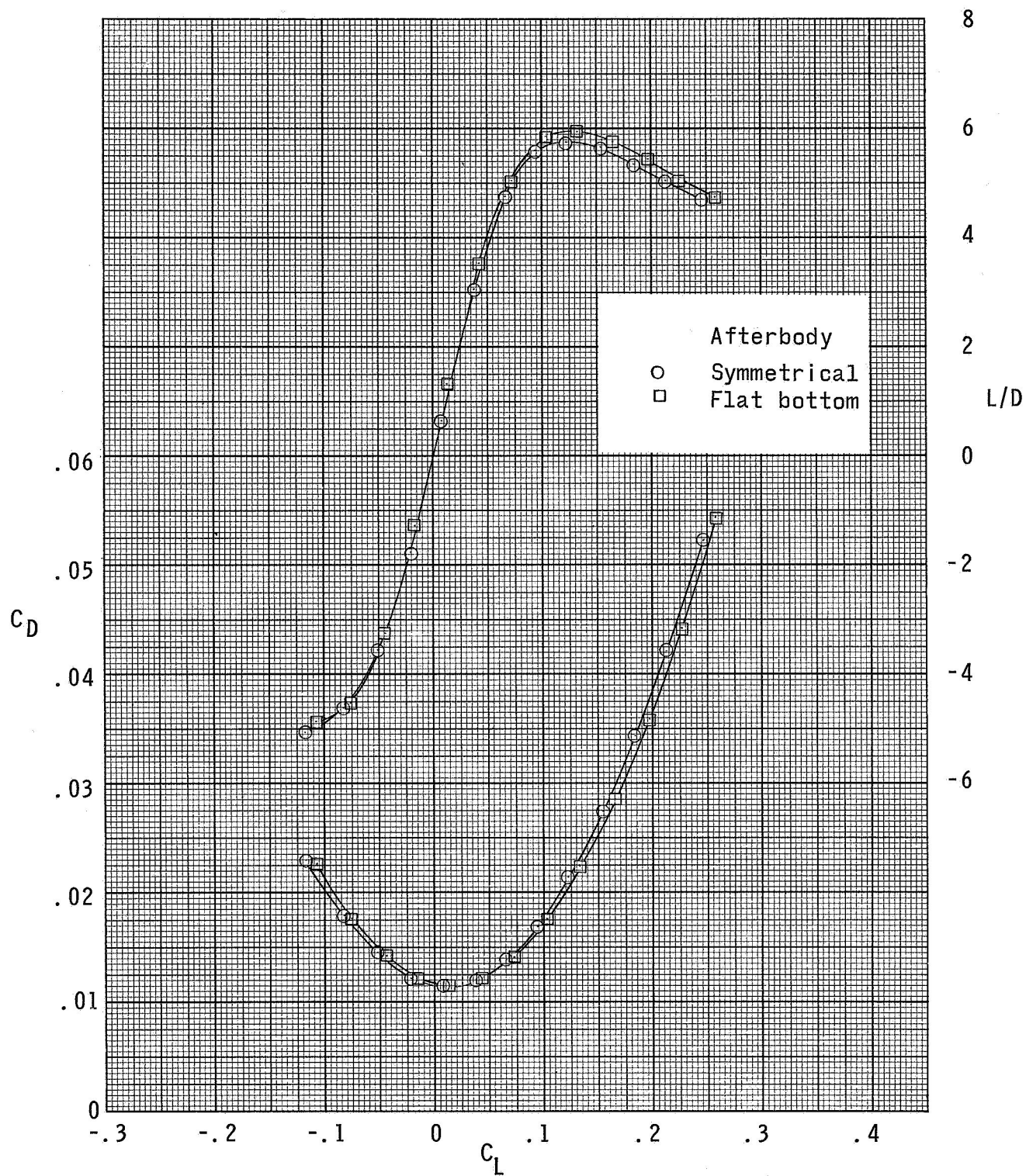
(b) $M = 3.35$. Concluded.

Figure 4.- Continued.



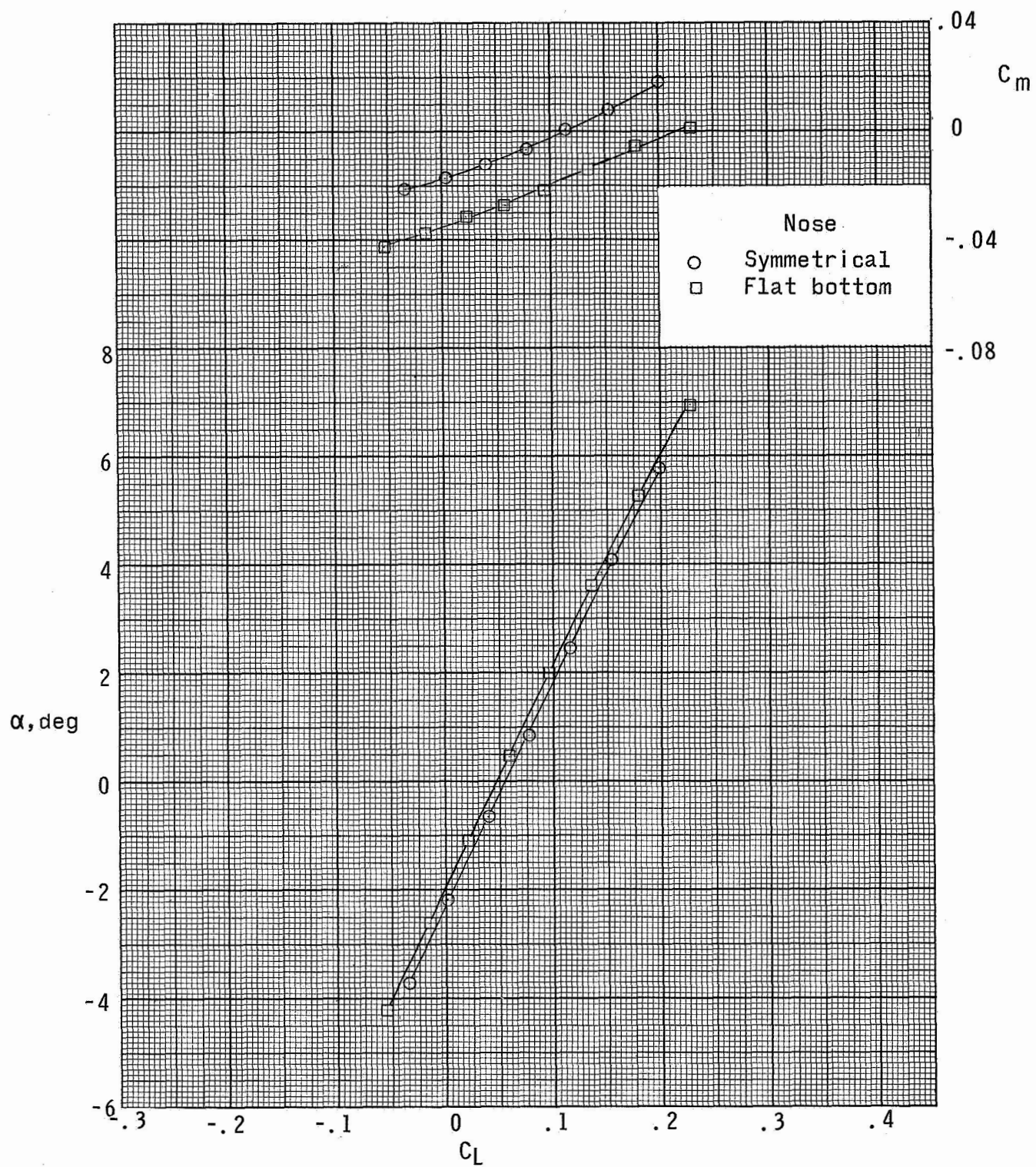
(c) $M = 3.70$.

Figure 4.- Continued.



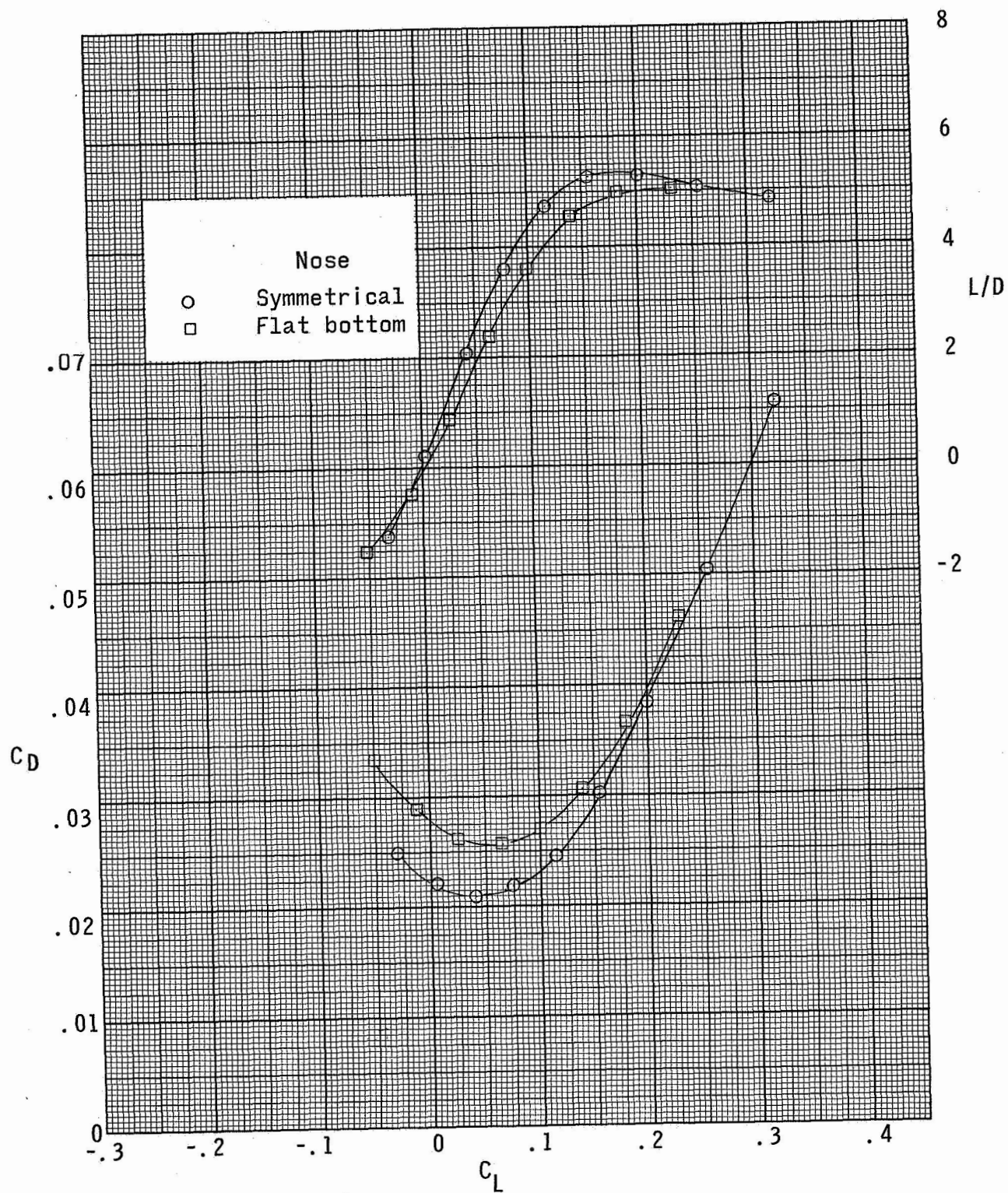
(c) $M = 3.70$. Concluded.

Figure 4.- Concluded.



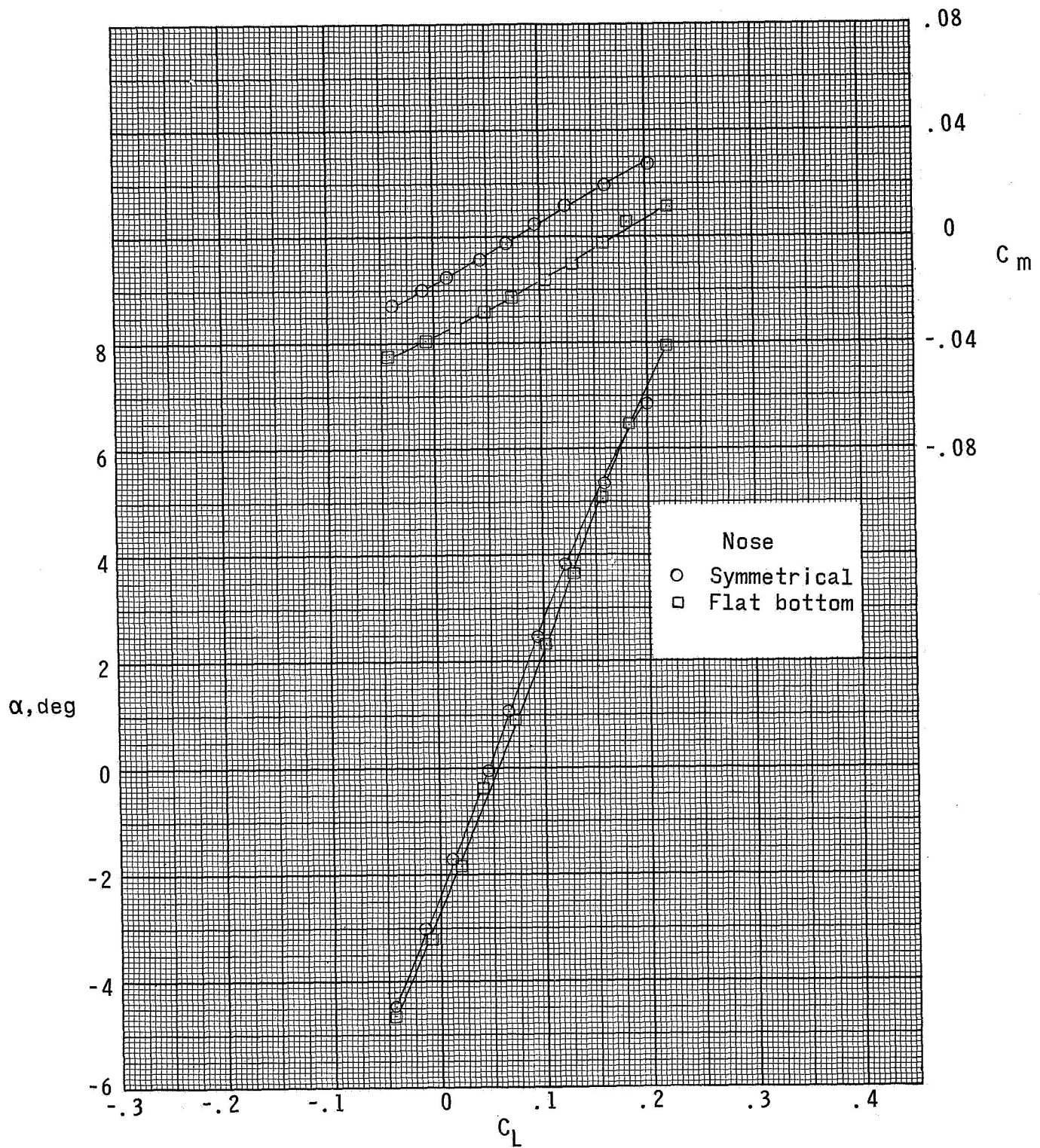
(a) $M = 2.16$.

Figure 5.- Effect of nose shape on the aerodynamic characteristics in pitch for the modified-half-ring-wing model with the flat-bottom afterbody.



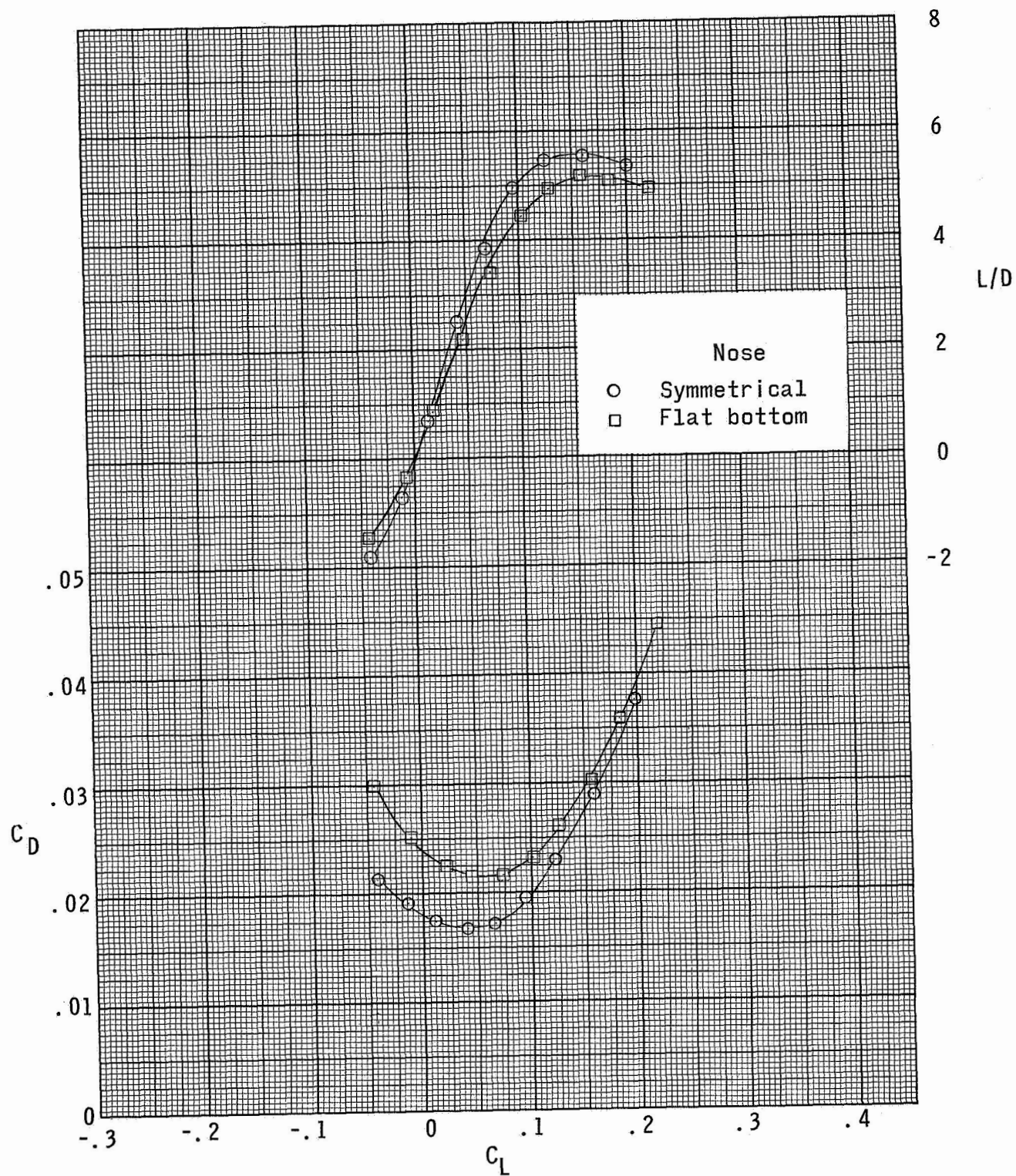
(a) $M = 2.16$. Concluded.

Figure 5.- Continued.



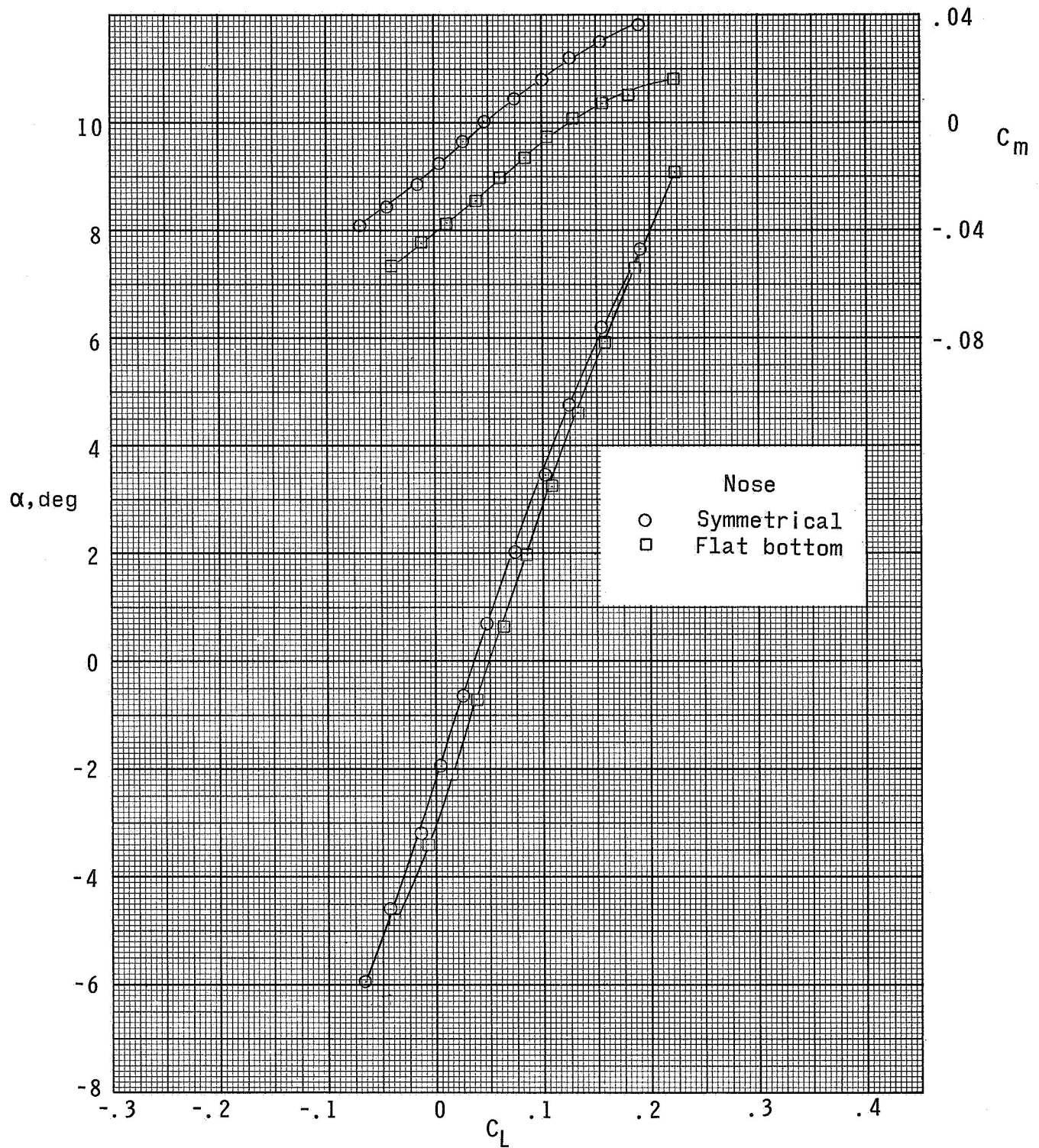
(b) $M = 2.50$.

Figure 5.- Continued.



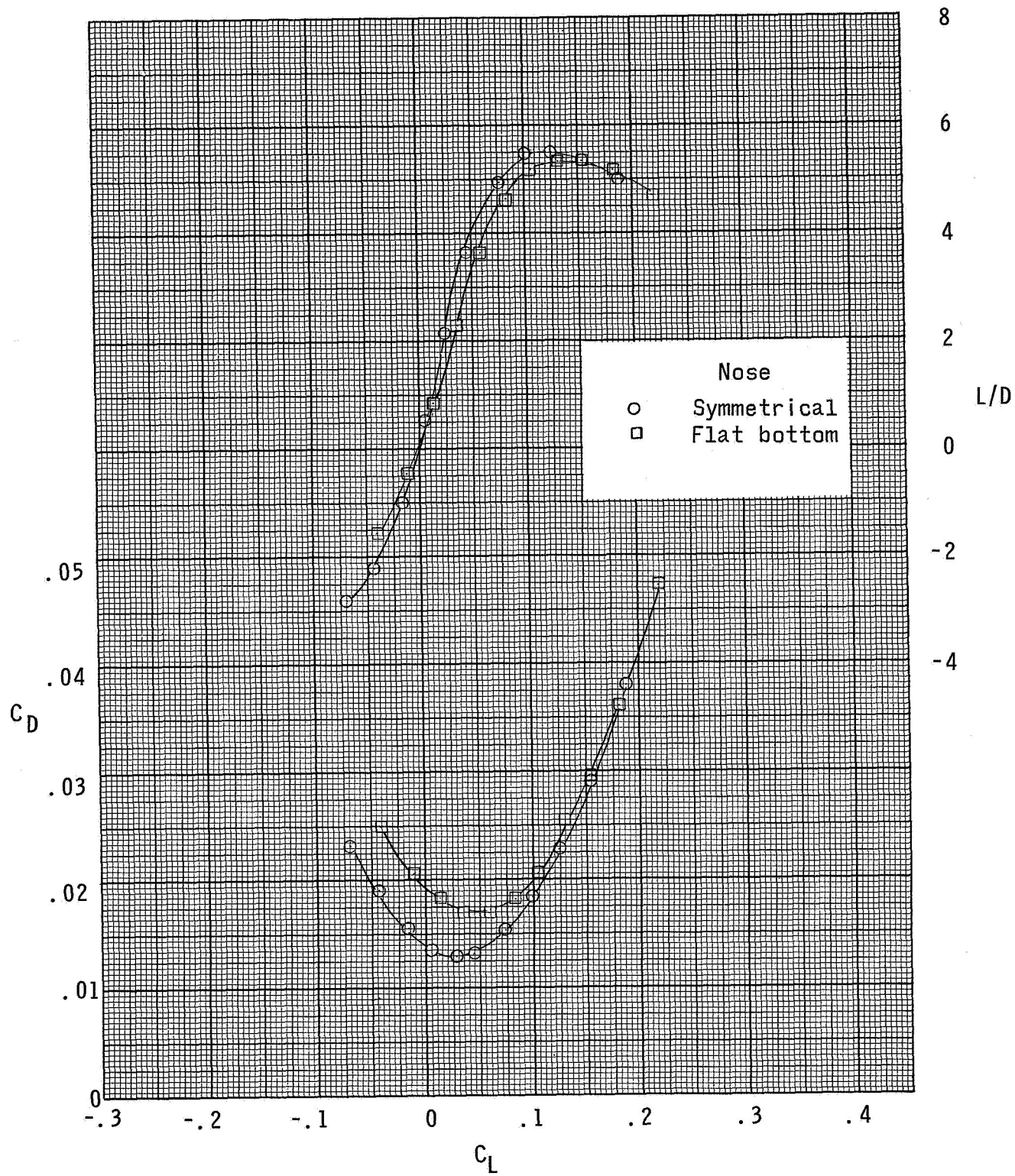
(b) $M = 2.50$. Concluded.

Figure 5.- Continued.



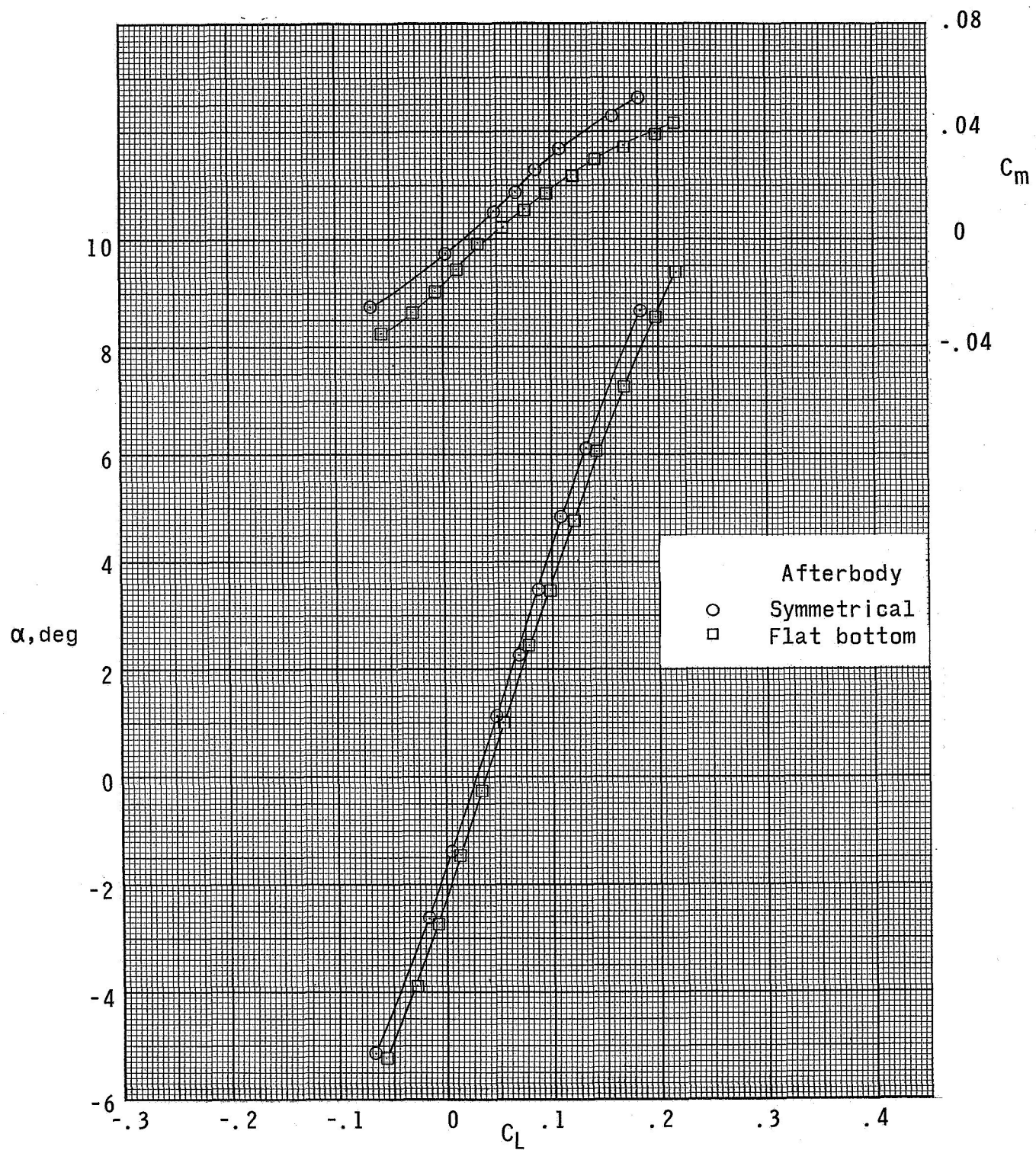
(c) $M = 2.86$.

Figure 5.- Continued.



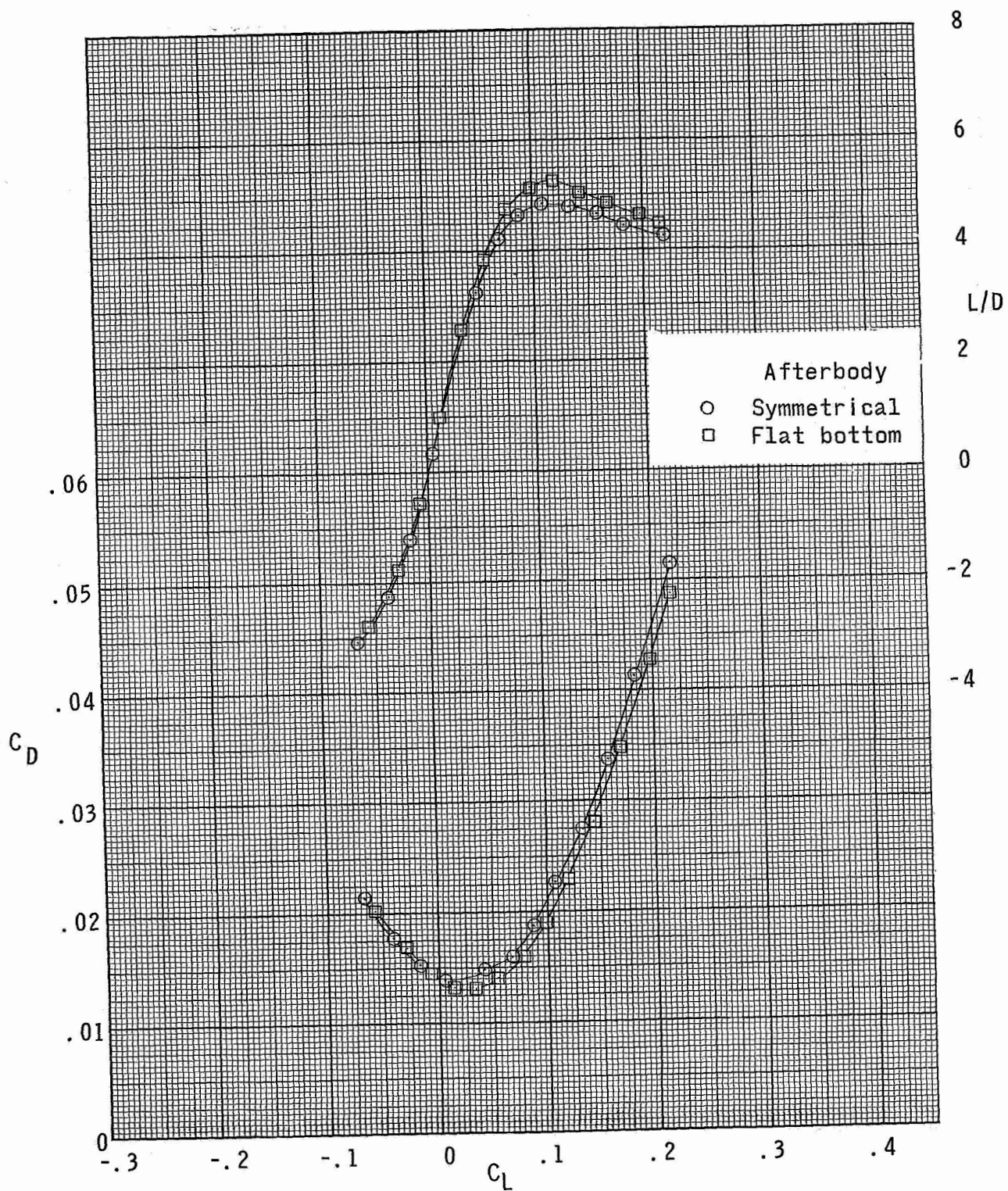
(c) $M = 2.86$. Concluded.

Figure 5.- Concluded.



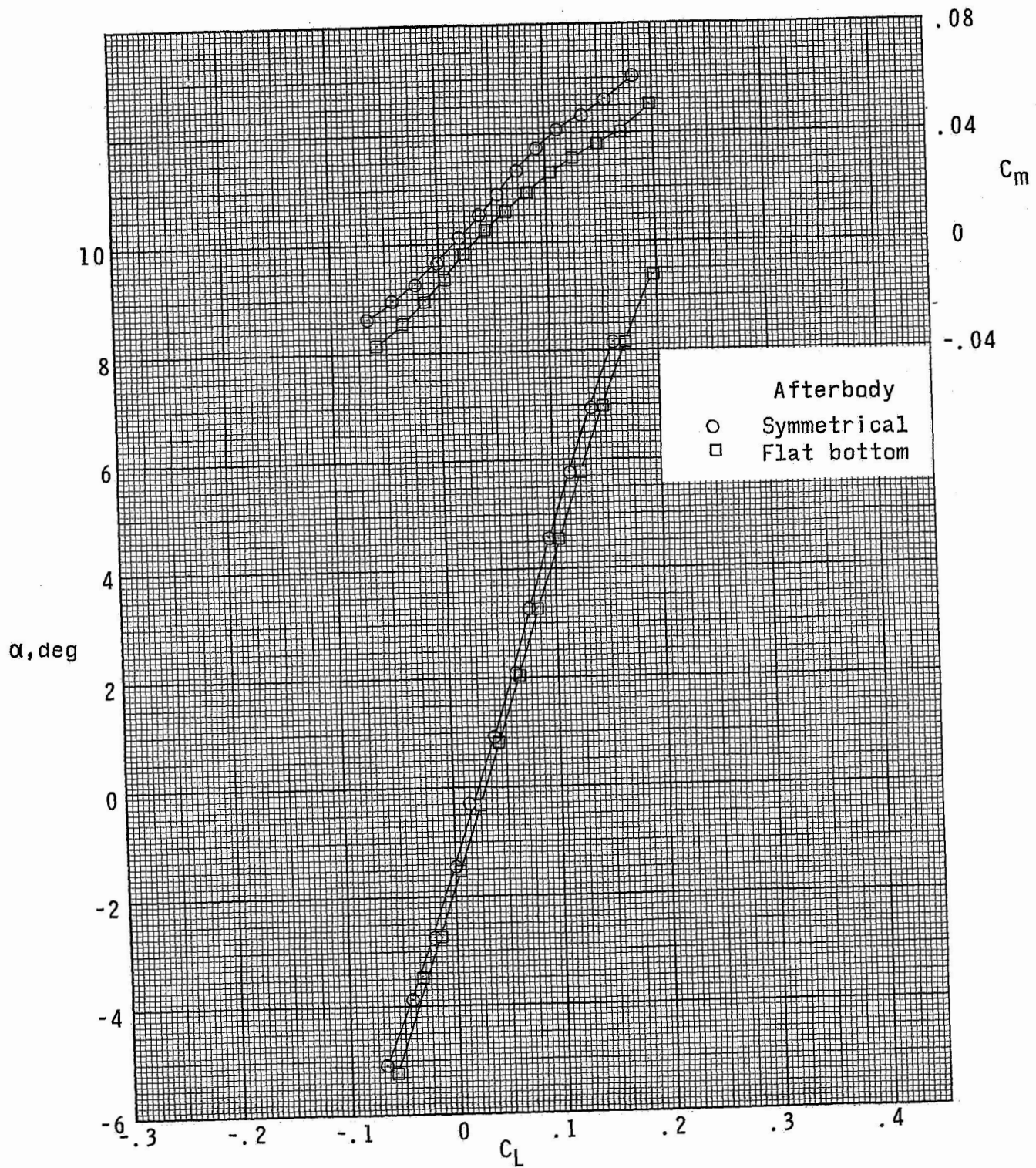
(a) $M = 3.00$.

Figure 6.- Effect of afterbody shape on the aerodynamic characteristics in pitch for the modified-half-ring-wing model with the symmetrical nose.



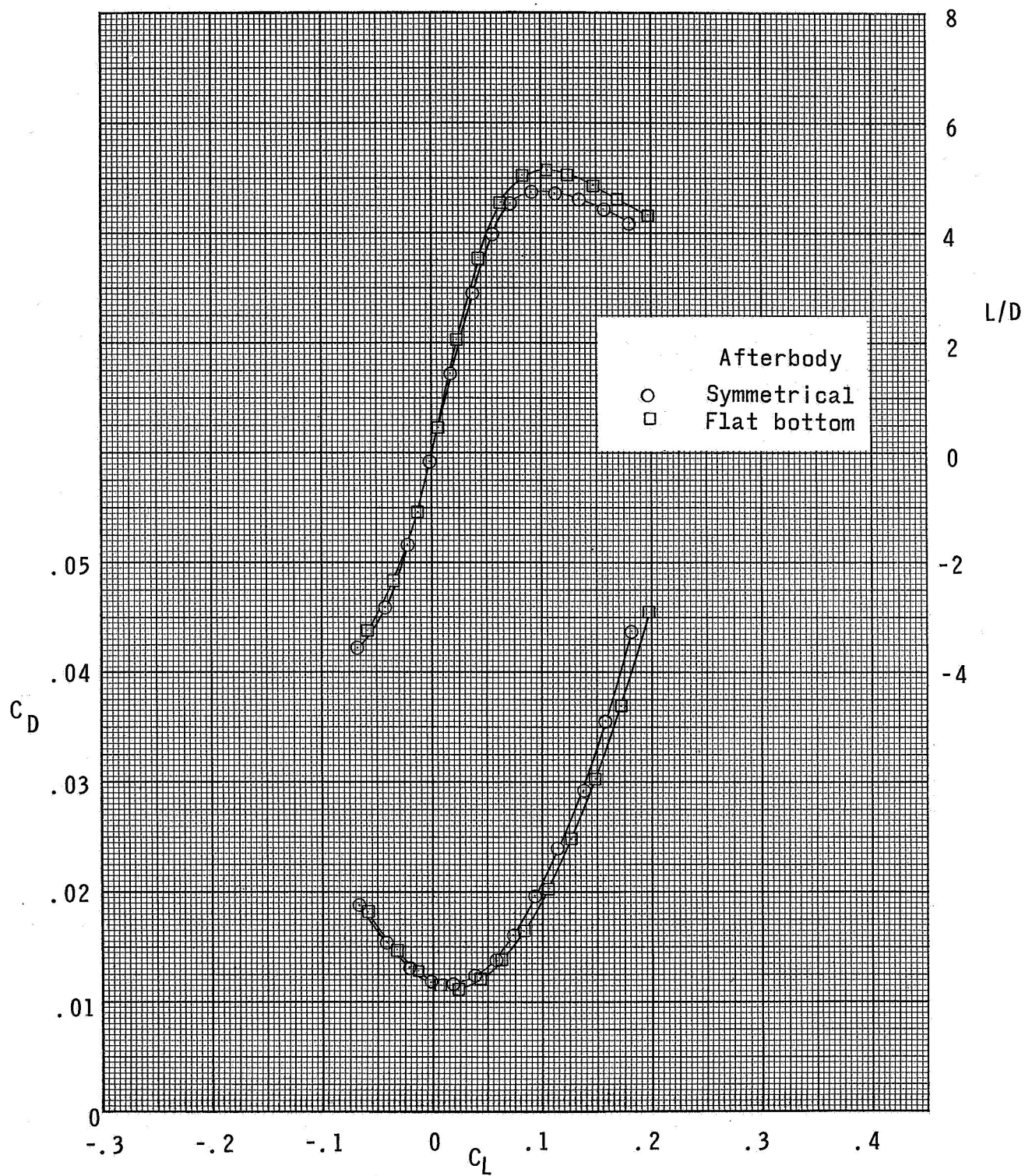
(a) $M = 3.00$. Concluded.

Figure 6.- Continued.



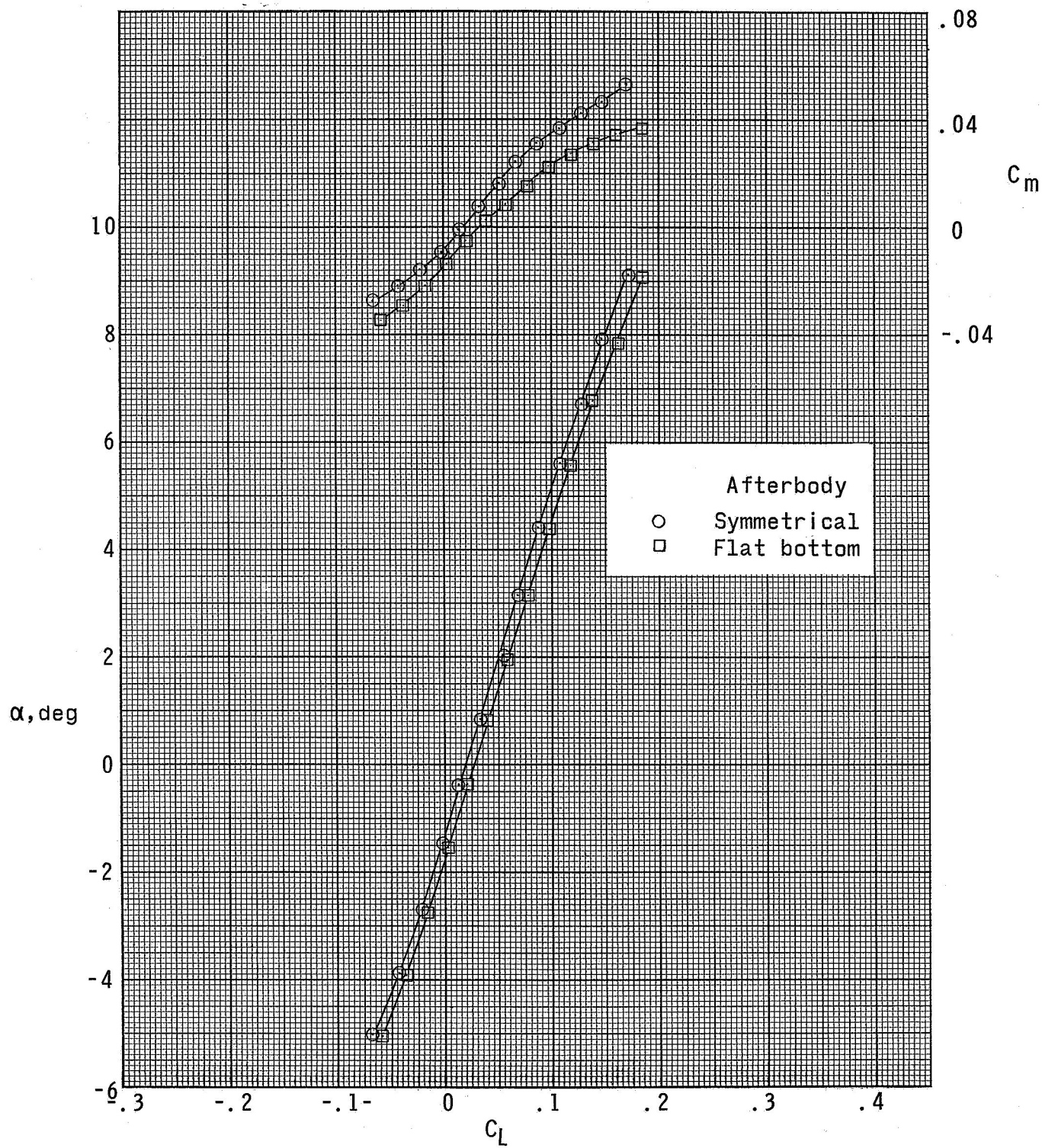
(b) $M = 3.35$.

Figure 6.- Continued.



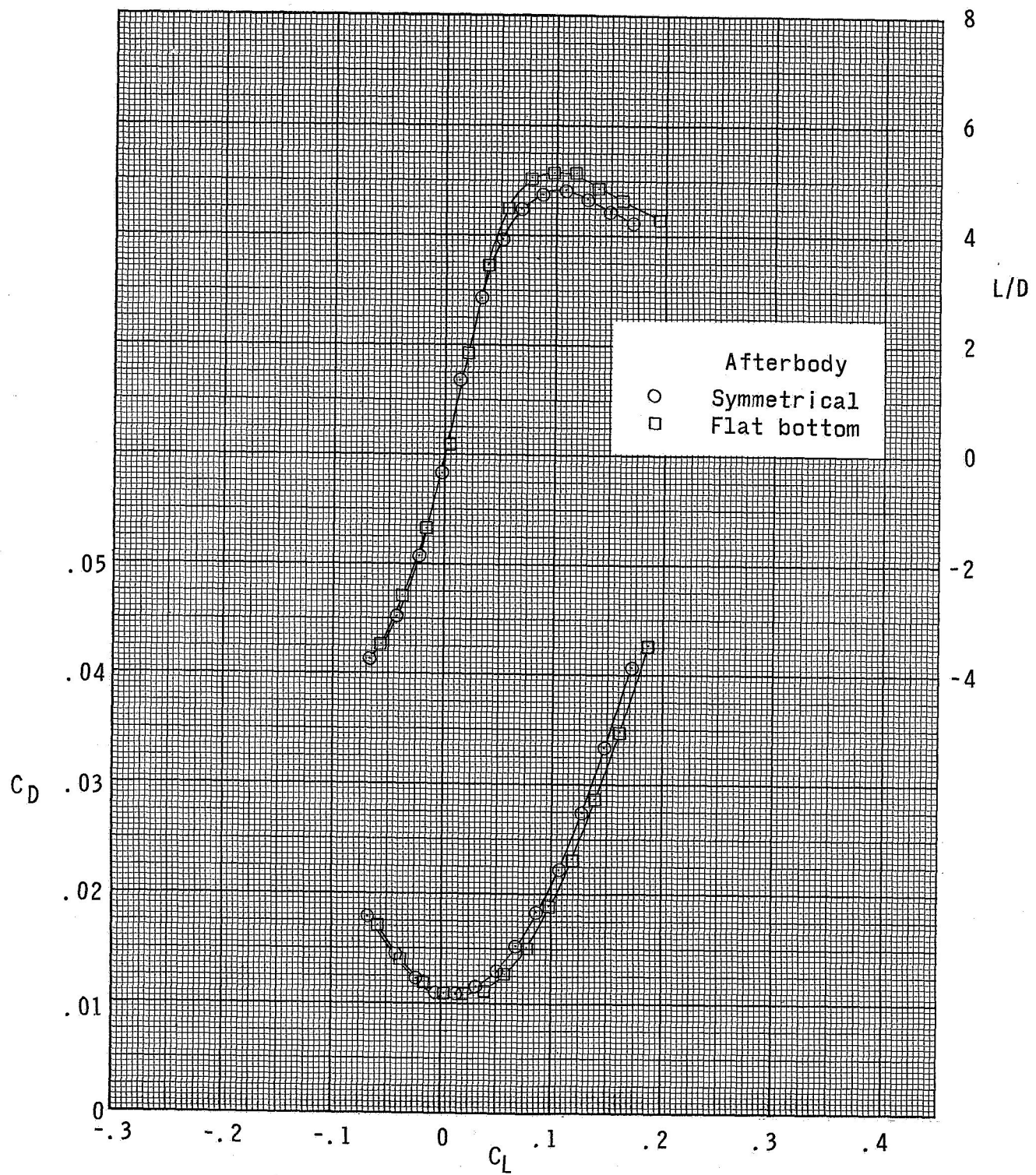
(b) $M = 3.35$. Concluded.

Figure 6.- Continued.



(c) $M = 3.70$.

Figure 6.- Continued.



(c) $M = 3.70$. Concluded.

Figure 6.- Concluded.

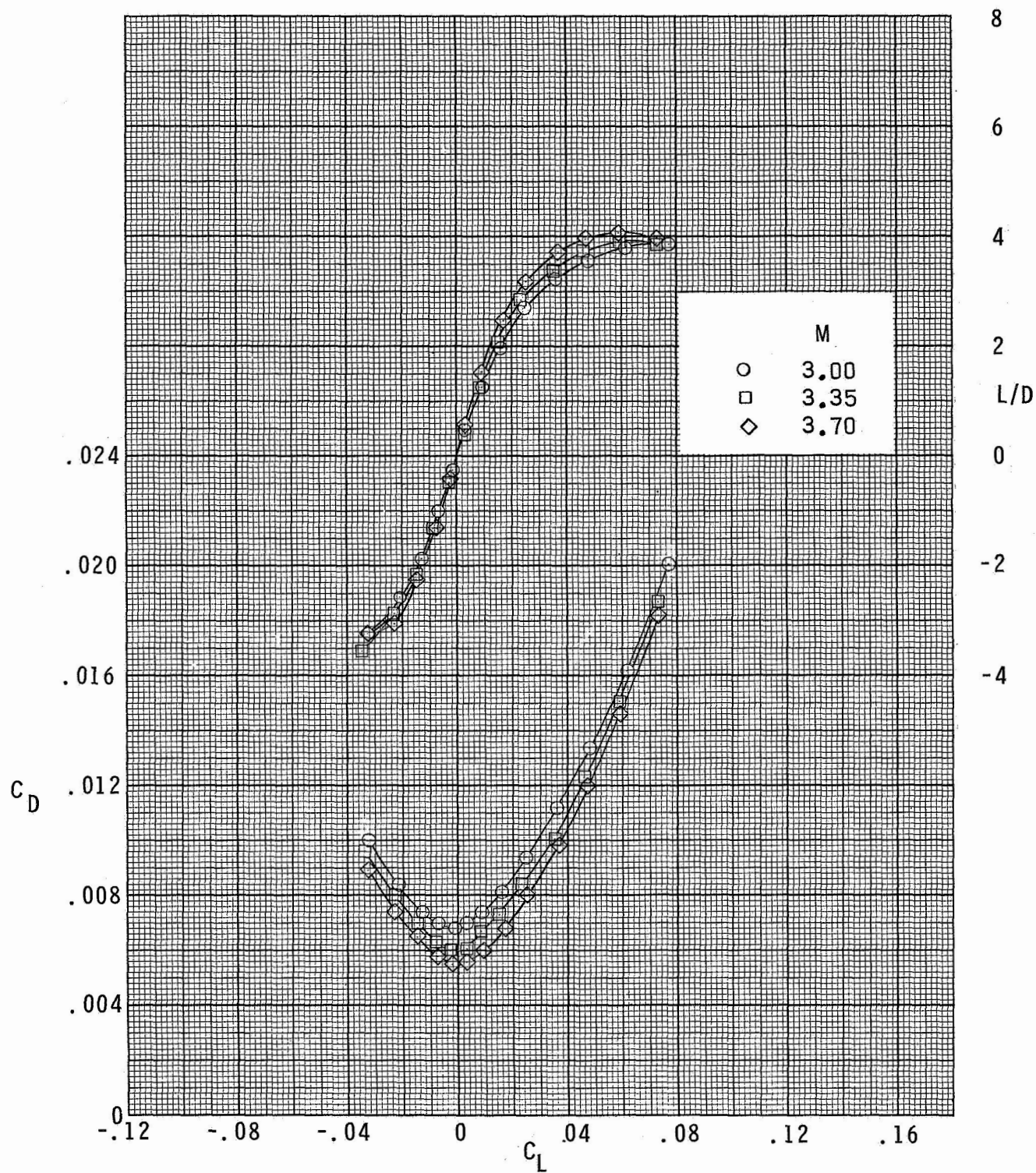


Figure 7.- Aerodynamic characteristics in pitch of the body alone with the symmetrical nose and afterbody at Mach numbers of 3.00, 3.35, and 3.70.

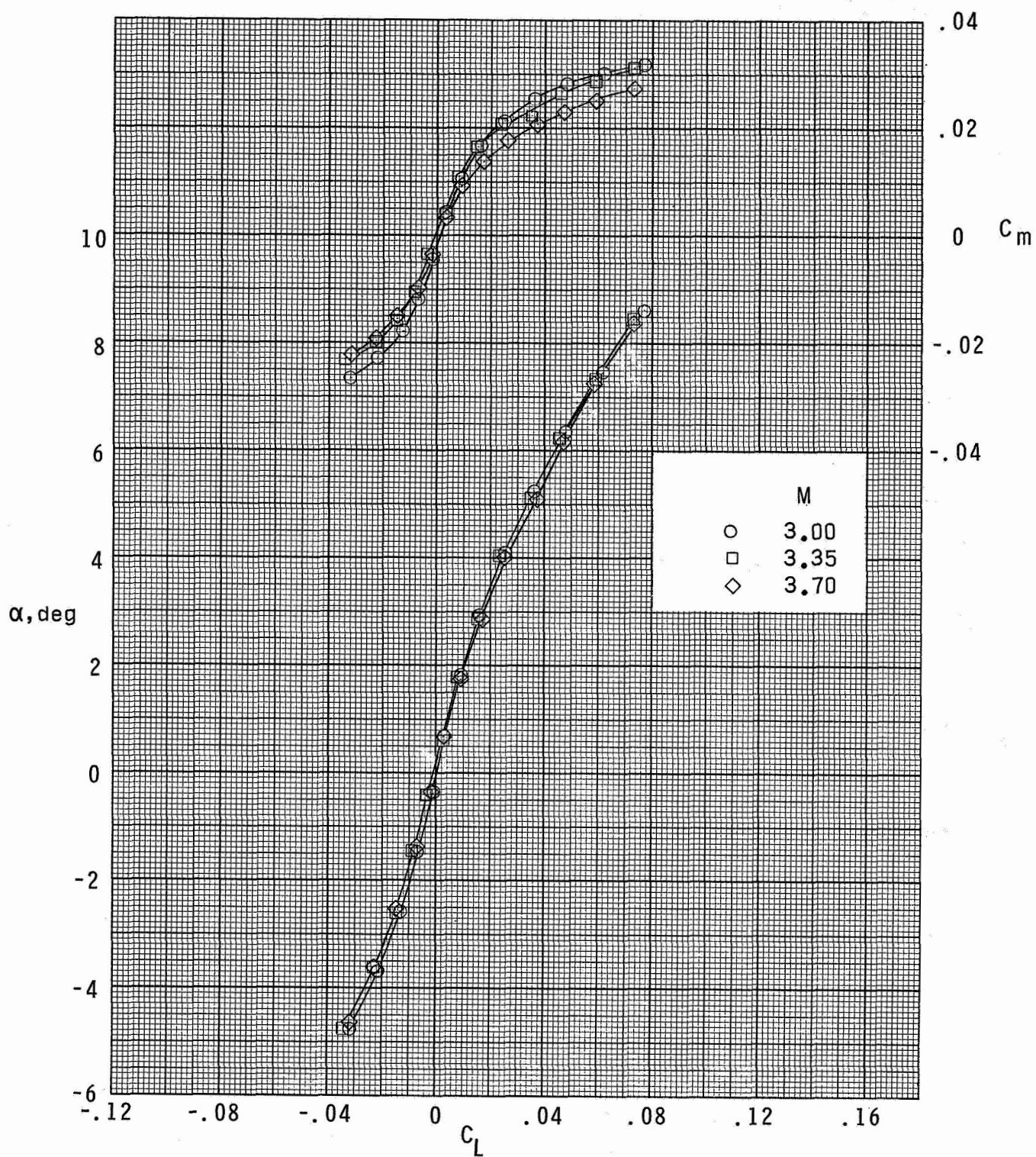


Figure 7.- Concluded.

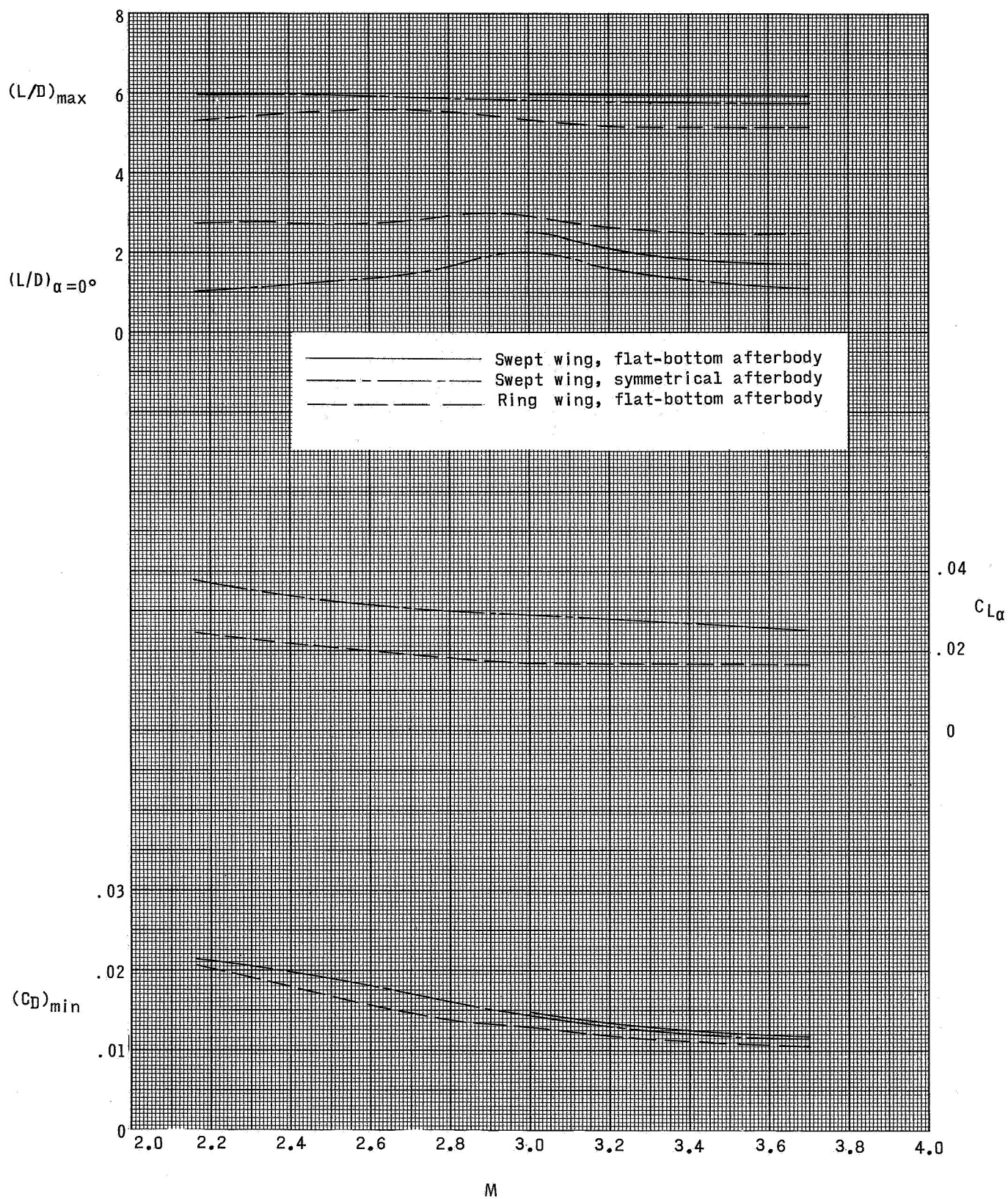
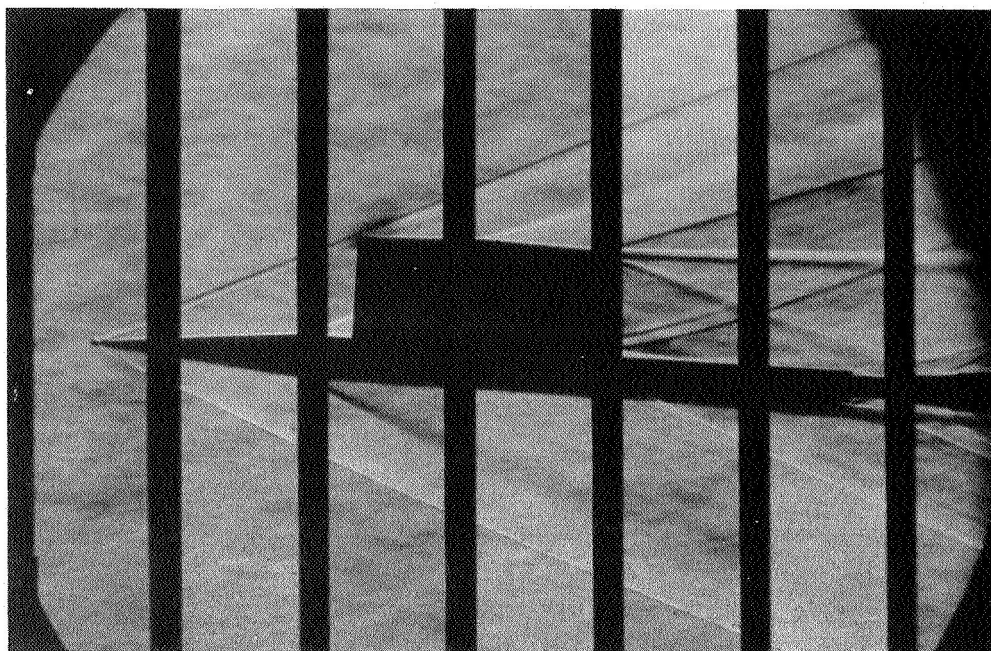


Figure 8.- Variation of the longitudinal parameters with Mach number for the two wing-body models with the symmetrical nose.



$$\alpha = 3.49^\circ$$

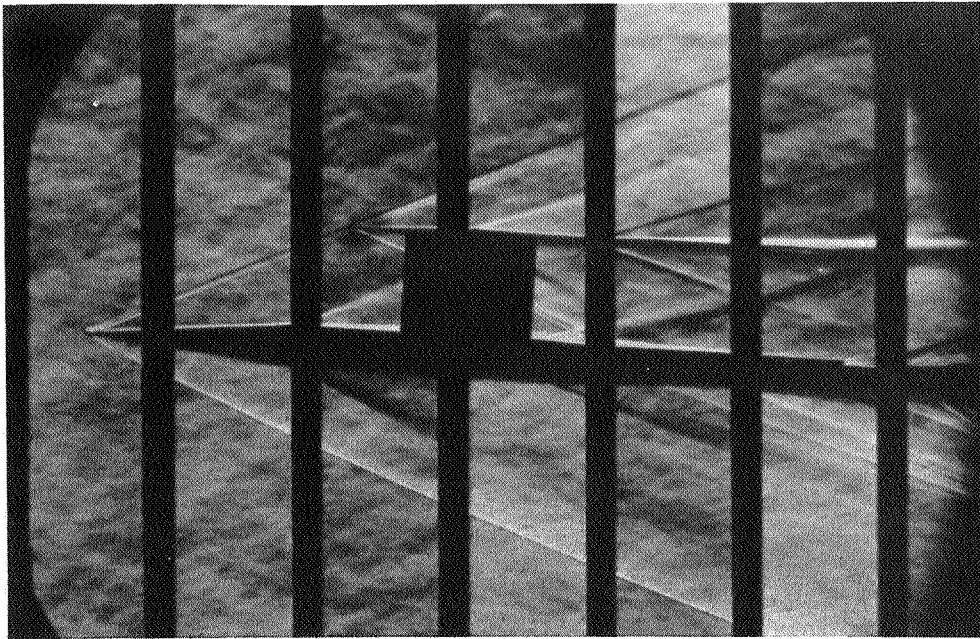


$$\alpha = -.24^\circ$$

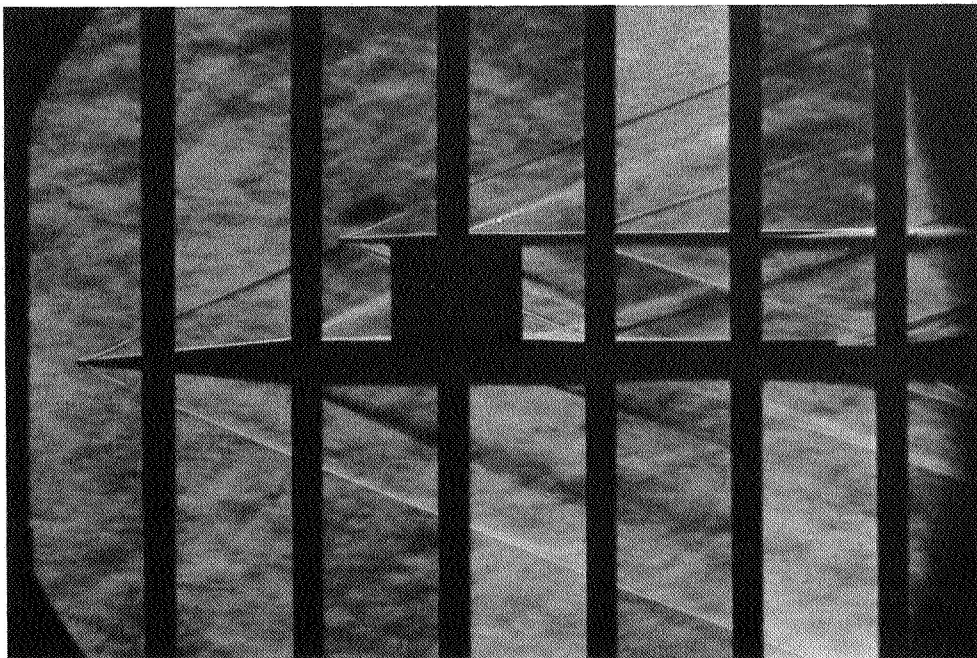
(a) Modified-half-ring-wing model.

L-68-812

Figure 9.- Schlieren photographs of the models at $M = 3.00$.



$$\alpha = 3.46^\circ$$



$$\alpha = -.21^\circ$$

(b) Swept-wing model.

L-68-813

Figure 9.- Concluded.

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